LAMK Lahden ammattikorkeakoulu
Lahti University of Applied Sciences

THERMAL MODIFICATION OF AYOUS AND FRAKE

Jartek Invest Oy

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Tiivistelmä

Opinnäytetyö käsittelee kokeellista tutkimusta kahden afrikkalaisen puulajin fraken ja ayouksen lämpökäsittelystä ja sen vaikutuksista puiden ominaisuuksiin. Tarkoituksena oli saada työn tilaamalle Jartek Invest Oy:lle tutkimustietoa lämpökäsittelyn hyödyllisyydestä kyseisille puulajeille.

Opinnäytetyön kirjallisessa osiossa käsitellään lämpökäsittelyä, sen vaikutusta puun ominaisuuksiin ja teollisessa käytössä olevia prosesseja. Kirjallisessa osiossa käydään läpi myös katsaus käsittelyssä olevien puulajien alkuperästä, ominaisuuksista ja yleisimmistä käyttökohteista. Lisäksi käytetyt standardit käydään läpi lyhyesti.

Työn kokeellinen osa alkaa materiaalin lämpökäsittelyllä ja testikappaleiden valmistamisella. Lämpökäsitellyt kappaleet testattiin käyttäen vertailukohtana saman puuerän käsittelemättömiä kappaleita. Puulajeille suoritettiin seuraavat kokeet: tasapainokosteus, mittapysyvyys, taivutus, halkaisu ja ruuvin irti vetolujuus, sekä Brinellin kovuus ja tiheys. Tuloksissa käydään läpi kaikkien testien tulokset ja niistä voidaan todeta, että puiden tasapainokosteus on pienentynyt suuresti ja mittapysyvyys parantunut huomattavasti. Lujuus ominaisuudet ovat heikentyneet kaikilla osa-alueilla.

Avainsanat

lämpökäsittely, ayous, Triplochiton screloxylon, frake, Terminalia superba

Abstract

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Abstract

This Bachelor's thesis is experimental research on thermal modification of two African wood species, frake and ayous, and what kind of impact it has on their properties. The goal of this work was to get data for Jartek Invest Oy about the usefulness of thermal modification for these species.

The literature part of the thesis is overviewing thermal modification process and what kind of changes is happening in wood in the process. There is also a chapter on thermal modification processes used in the wood industry. The literature part includes overview chapters for wood species and standards used in the experimental part.

The experimental part starts with thermal modification of the materials and preparation of the test pieces. Following tests were performed for the test pieces: Equilibrium moisture content, dimensional stability, bending, cleavage, screw withdrawal, Brinell hardness and density. From the results can be seen, that while equilibrium moisture content has decreased and dimensional stability is vastly improved, the strength values have gone down on all areas for both wood species.

Keywords

thermal modification, ayous, Triplochiton screloxylon, frake, Terminalia superba

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1 INTRODUCTION

The goal of this thesis is to examine the effect of thermal modification on two African wood species ayous (Triplochiton screloxylon) and frake (Terminalia superba). The topic came from Jartek Invest Oy.

Jartek Invest Oy is a Finnish family-owned company. It was founded in 1957 as Sateko Oy. Currently Jartek is a leading supplier of sawmilling technology in Finland and the leading global supplier of thermal modification technology.

It is known that thermal modification affects the properties of wood by lowering its equilibrium moisture content, which makes the wood better in dimensional stability and durability. At the same time thermal degradation decreases the mechanical properties, such as bending strength. The amount of effect on these properties is to be studied with experimental research. The studied properties of ayous and frake and the standards used in this work are the following:

- EN 318 Dimensional stability
- EN 408 Bending strength
- ISO 6506- 1 Brinellin hardness
- SKH-BGS-002 Screw withdrawal
- ASTM D- 143 Cleavage

The main purpose is to find out the impact of thermal modification on ayous and frake and its usefulness for these species. The even results of consecutive treatments is also studied.

2 THERMAL MODIFICATION

In terms of protecting wood, surface treatment of is not always possible. Because of this, some treatments have been developed to decrease the hygroscopicity of wood. The most practical way to accomplish this is to modify the structure of the wood cell wall by heat. This way there is no need to use chemicals, that are in many cases harmful for the environment. (Kärkkäinen 2007, 207.)

In thermal modification process the structure and the properties of a wood cell wall are changing. There is already some variation in these properties when comparing artificially dried wood to outdoor dried wood. Actual thermal modification happens in high temperatures between 170 °C and 240 °C (Kärkkäinen 2007, 207). In such high temperatures wood is affected by thermal degradation and it basically means that the wood starts burning. This reaction can be controlled by removing oxygen from the treatment chamber. Usually it is dealt with by performing the treatment in an atmosphere where oxygen is absent, for example in steam or nitrogen gas. (Sandberg, Kutnar & Mantanis 2017.)

In the 21st century thermal modification has been developed to an excellent method, which has many successful products around the globe. As, the concern about environmental issues is only growing the pressure on traditional biocide-treated wood is increasing and their use is most likely to become even more restricted. Chemically and thermally modified wood provides environmentally friendly solutions, and for this reason their market area is expected to grow. (Gerardin 2015.)

The rise in Thermowood production numbers is a good example of an increasing demand for thermally modified wood. In year 2001, the Thermowood production was 18,799 m^3. Since then the production volume has grown steadily and in 2016 the numbers were nearly tenfold, reaching 179,507 m^3. (Figure 1.)

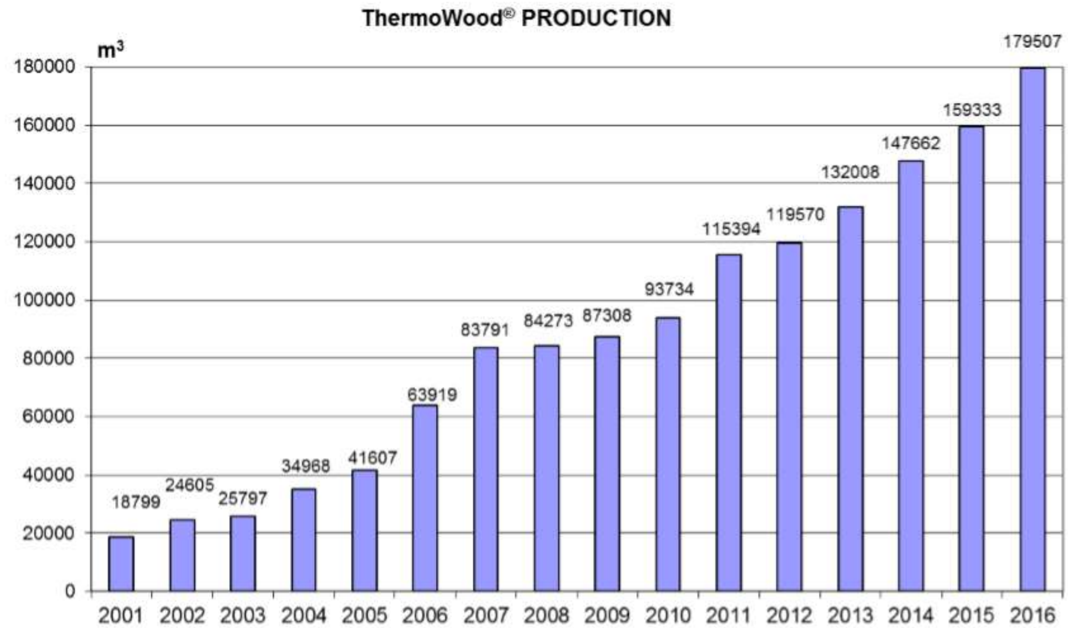


FIGURE 1. Thermowood production numbers (Thermowood Handbook)

2.1 Changed properties of wood

With thermal modification there come both desired and undesired changes. In most cases they strongly correlate with each other. Higher temperatures and longer treatment times decrease the equilibrium moisture content of wood and give it better dimensional stability. At the same time degradation in the wood cell wall increases, which leads to decreasing mechanical properties.

The decrease of equilibrium moisture content that is achieved with thermal modification is around 40 % compared to untreated wood of the same species. Research has shown that it is possible to improve dimensional stability of wood by 90 %. Thermal modification also has a positive impact on the durability of wood. After the treatment it is more durable, being resistant for rot inducing fungi and insects. (Kärkkäinen 2007, 208.)

Degradation of the cell wall causes unwanted changes in mechanical properties of wood. The changes correlate strongly with the loss of density that happens during the treatment. Thermal modification changes the appearance of wood, deepening the colour to darker brown. Thermal modification is used to give some more common species like birch or beech a more exquisite look and they can be used to replace more expensive exotic wood species in furniture and decoration (Sandberg et al. 2017.)

2.2 Industrial methods

Many different thermal modification methods are used in the wood industry around the world. The aspect that is common for all of them is high treatment temperature, around 160-240 °C.

2.2.1 Thermowood

The Thermowood is the most widely used thermal modification method (Sandberg et al. 2017) The process has been created by VTT (Technical Research Centre of Finland Ltd) together with the Finnish wood industry. Wood is treated at a minimum temperature of 180 °C, protected with water vapour. The Thermowood process is divided in three steps. It can be started with both dried and fresh wood. In the first step the temperature is brought quickly up to 100 °C. After this the temperature will be steadily increased to 130 °C where the moisture content of wood is brought close to a zero level by high-temperature drying. The second step is where the thermal modification takes place. The temperature is increased to 185-215 °C, depending on the class of the finished product. Wood material is kept at this treatment temperature for 2 to 3 hours. In the last step the kiln is cooled down to 80-90 °C by a water spray system. Thereafter the wood material is re-moisturised to moisture content level of 4-7 %. (Thermowood Handbook 2003.)

2.2.2 Plato

The Plato-process is a heat treatment method from the Netherlands. Its name comes from Proving Lasting Advanced Timber Option. It is comprised of hydro thermolysis and dry curing steps and the treatment medium can be either steam or heated air. The process starts with hydro thermolysis, which is performed under super atmospheric pressure at a temperature of 160-190 °C. During the first step there is plenty of water in the wood cell wall that makes it more reactive in relatively low temperatures. Before the second step the treated material is dried in the ordinary fashion to around 10 % of moisture content. The second treatment step is called curing. The dried wood is heated again to temperatures between 170 °C and 190 °C. Afterwards the treated material is conditioned by cooling it down and re-moisturising it. The process is quite lengthy and can take 100 hours in total. It can be shorter depending on the treated wood species and dimensions of the material. (Militz & Tjeerdsma 2001.)

2.2.3 Retification

Retification is one of the thermal modification methods mainly used in France. New Option Wood (NOW) holds the licences for the method that was developed by Ecole des Mines de Saint-Etienne. NOW, also known as Retitech, has developed this method further to match the industrial needs. (Vernois 2001.)

The treatment happens in a nitrogen atmosphere at a temperature between 210 °C and 240 °C where wood undergoes a mild pyrolysis reaction. Wood material must be dried to around 12 % of water content before treatment. Treatment time is from 8 to 24 hours depending on the material. (Vernois 2001.)

2.2.4 Le Bois Perdure

Another main heat treatment method in France is called Le Bois Perdure. The process starts with fresh wood. After the drying phase the temperature inside the treatment chamber is raised up to 230 °C. The water that has been extracted from wood is now in steam form and works as a shielding gas. Depending on the material the process length is 12-36 hours. (Sandberg et al. 2017.)

2.2.5 Oil Heat Treatment

Menz Holz from Germany has created a thermal modification method that uses natural oil as a treatment medium. Oil transfers the heat evenly and efficiently into the wood during the process. Linseed has been proven suitable for this process. Other natural oils can also be used as long their boiling point is higher than 230 °C. (Rapp & Sailer 2000.)

Oil heat treatment uses a closed process vessel. The vessel is loaded with wood and filled with hot oil. During the treatment, heated oil circulates in between the treated wood. Oil temperature of 220 °C is used to obtain minimum oil consumption. Lower temperatures of 180 °C to 200 °C are used to get better mechanical properties for the finished product. Treatment time is usually around 18 hours. (Sandberg et al. 2017.)

3 TESTED WOOD SPECIES

Wood material for the experiments was provided by Jartek Invest Oy. Ayous and frake are both exotic wood species from Central Africa. In the following chapters we will take a better look at their origin and characteristics.

3.1 Ayous

Ayous (Triplochiton screloxylon) is also known as African whitewood, African maple, wawa, abachi, obeche and samba. It is a decidious tree that is naturally distributed from West to Central Africa (Figure 2). Ayous is commonly planted in that area and infrequently elsewhere, like in Solomon Islands. (Bosu & Krampah 2005.)

FIGURE 2 Natural distribution of ayous and frake. (Bosu & Krampah 2005)

Ayous (Figure 3) can reach a total length of 50 meters and it has a branchless bole up to 30 meters long. The buttress can be up to 8 meters long. The diameter of the tree reaches up to 150 cm and in some cases over 200 cm. The bark thickness is from 7-30 mm thick and grey to yellowish brown. Young trees have a smooth bark, but it gets scaly with age. (Bosu & Krampah 2005.)

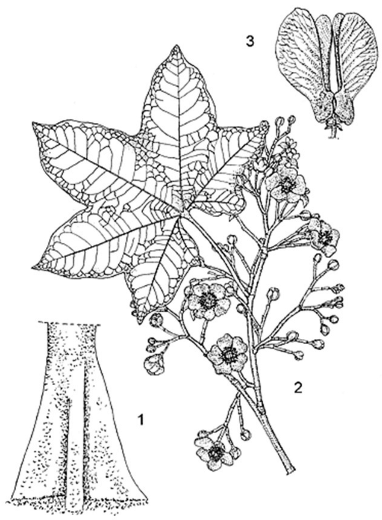


FIGURE 3. Drawing of ayous where: 1 is base of bole, 2 is flowering twig, and 3 is fruit.

3.1.1 Properties

The colour of the heartwood is whitish to pale yellow. Sapwood is up to 15 cm thick and the difference between it and heartwood is indistinctive. The timber works well in drying with only a small risk of distortion and checking. (Bosu & Krampah 2005.)

Ayous is a light material but, related to weight, its strength values are good (Table 1). The durability of the timber is poor for it is vulnerable to fungal attacks and different kinds of insects, so it should not be used in ground contact or exposed to weather. Bosu & Krampah 2005.)

TABLE 1. Properties of ayous (Bosu & Krampah 2005)

Ayous at 12% moisture content	
Density (12%)	320-440 kg/m³
MoR	52-110 N/mm²
MoE	4800-9200 N/mm²
Cleavage	5-15 N/mm
Janka Hardness	1910-2100 N

3.1.2 Uses

Ayous is an important element in local house building and is widely used as sawn timber. It is used from interior joinery to pencils and is especially suitable for making shipping crates and boxes, due to its light weight. (Bosu & Krampah 2005.)

3.2 Frake

Frake (Terminalia superba) shares its natural growing area with ayuos in West and Central Africa (Figure 2). It belongs to the Comvretacea family. It has many names but is commonly known in European markets as frake or limba. Outside its natural growing area, it has been used as a potential plantation species. (Kimpouni 2009.)

Frake is a large or middle sized deciduous tree that can grow up to 50 m high (Figure 4) and it can reach a bole diameter of 150 cm. Annual growth of the tree is up to 2.5 meters. In good conditions it can reach a trunk diameter of 50 cm in 20 years. Frake is self-pruning so it can have a tall branchless trunk. The branchless trunk is usually straight and cylindrical being up to 35 meters long. The buttress is large with plank like appendages and it can be 8 meters tall. (Kimpouni 2009.)

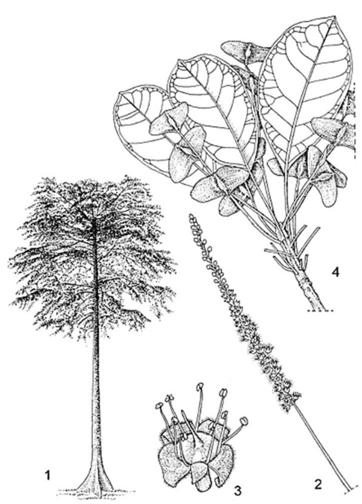


FIGURE 4. A drawing of frake where: 1 is tree habit, 2 is inflorescence, 3 is flower and 4 is fruiting branch with leaves.

Depending on the growing region, the size of a harvestable log varies from 50 to 70 cm diameter. In plantations the harvesting cycle is usually limited to 40 years but in optimal circumstances it could be even 20-25 years. (Kimpouni 2009.)

Frake belongs to the most important lumber producing wood species in tropical Africa. However, it seems that the natural reserves of the tree are slowly depleting, and no change of that progress is to be noticed. Frake is well suited for plantation use because of its fast growth speed. To be able to preserve the present natural resources exploiting of the plantation should be increased. (Kimpouni 2009.)

3.2.1 Properties

The colour of the frake's heartwood is from greyish brown to light reddish brown. The sapwood is 12-15 cm thick and it is difficult to differentiate from heartwood. The grain pattern is usually straight, and the texture of the material is slightly coarse. (Kimpouni 2009)

As a material frake, is easy to work with machines and hand tools. There is only a little blunting effect with cutting blades. It glues adequately and finishes well with a filler. The density of frake varies considerably (Table 2). This leads to irregular strength properties. (Kimpouni 2009.)

TABLE 2. Properties of Frake (Kimpouni 2009)

Frake at 12% moisture content	
Density (12%)	430-730 kg/m^3
MoR	50-133 N/mm^2
MoE	4700-14300 N/mm^2
Cleavage	7.5-23.5 N/mm
Janka Hardness	3020 N

3.2.2 Uses

Frake is a valuable resource in interior joinery and is used widely from light construction to toothpicks. It is used especially for making veneer and plywood and can also be used in making paper.

4 STANDARDS

4.1 SFS-EN 408

In 2012 this standard replaced its earlier form from 2011. It deals with determining specific properties for timber structures, structural timber and glued laminated timber. In this work the global modulus of elasticity and the global bending strength are determined with the methods of this standard.

4.2 SFS-EN 318

This standard is from 2002 and it replaces the former version from 1982. EN 318 is a standard for determining dimensional changes in wood-based panels associated with the changes in relative moisture content of air. In this thesis it is used to determine the dimensional changes in solid wood.

4.3 SFS-EN ISO 6506

This standard is from 2014 and it replaces the former version from 2006. ISO 6506 is a standard for determining Brinell hardness for metallic materials. In this thesis the parameters used to determine HBW 10/100 hardness are used to determine the hardness of solid wood test specimens.

4.4 SKH-BGS-002

SKH-BGS-002 is a certificate from the Netherlands for the assessment of screws used in solid wood and wood-based panels. The screw withdrawal perpendicular to wood grain is executed according to this certificate.

4.5 ASTM D 143

This American standard is from the year 1994 and it has been reapproved in 2000. It deals with test methods for small specimens of wood without defects. In this work, the cleavage test is made according to this standard.

5 EXPERIMENTS

The practical part of this thesis was done in the premises of Lahti University of Applied Sciences. Test materials arrived as dried sawn lumber. There were 30 planks of both species. They both were of good quality with very small amount of knots, if any. Material length of both species was 2500 mm. Dimensions for ayous were 32 mm of thickness and 180 mm of width. In frake the thickness was 45 mm and width 120 mm. In order to make reference test pieces a 800 mm piece was sawn from each plank. The separated pieces were marked with matching numbers (Picture 1).

PICTURE 1. Reference pieces and boards going to thermal modification with matching numbers.

5.1 Thermal modification

Thermal modification was performed in Tekma Wood (currently Jartek invest Oy) thermal modification kiln with the help of Jartek Invest Oy. They provided programs and professional knowledge for the treatment process. One goal was to prove the repeatability of thermal modification at the temperature of 220 °C for the used species. It was done by splitting the materials in two treatment batches. Both batches had ayous stacked at the bottom and frake on top of them. The test materials only filled half of the kiln. To ensure a stable airflow within the treatment batch the excess space was filled with pine boards (Picture 2). Sensors for wood temperature and moisture content were installed in frake planks.

PICTURE 2. First batch after the treatment in kiln

The treatment program followed the temperature and moisture content that was monitored in real time from frake. The thermal modification phase took place at 220 °C and that temperature was held for 2 hours. After that started the cooling and re-moisturising. The process time for the first batch was 90 hours (Picture 6) and 95 hours for the second batch (Picture 7). The mean end moisture content was measured from both batches with a Gann Hydromette moisture meter. The end moisture content after batch one was 4.5 % for ayous and 6.0 % for frake. For the second batch values for Ayous were 3.7 % and 4.7 % for frake.

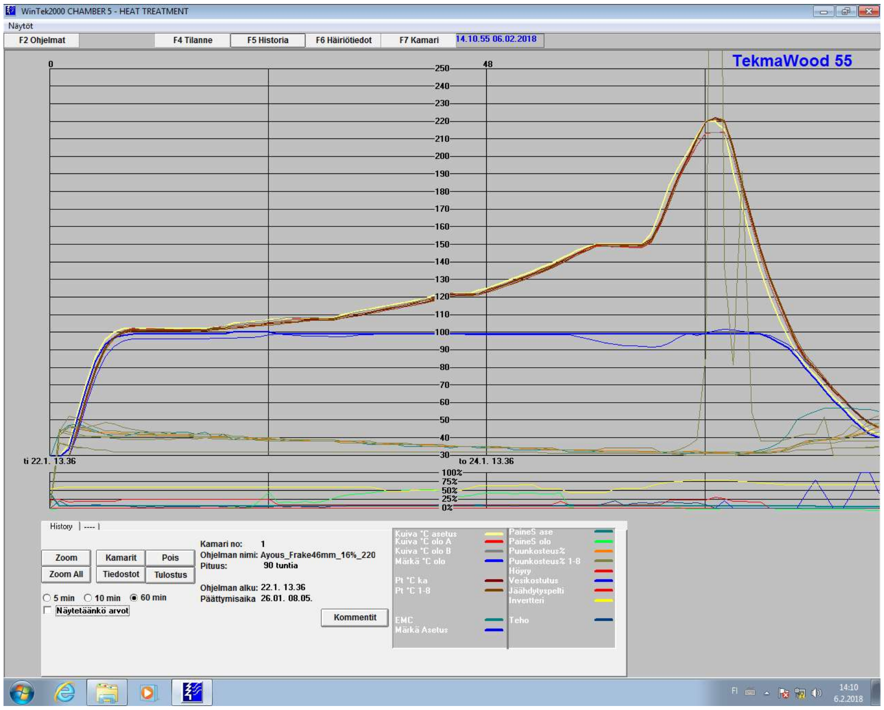


FIGURE 5. Program curve of the first batch

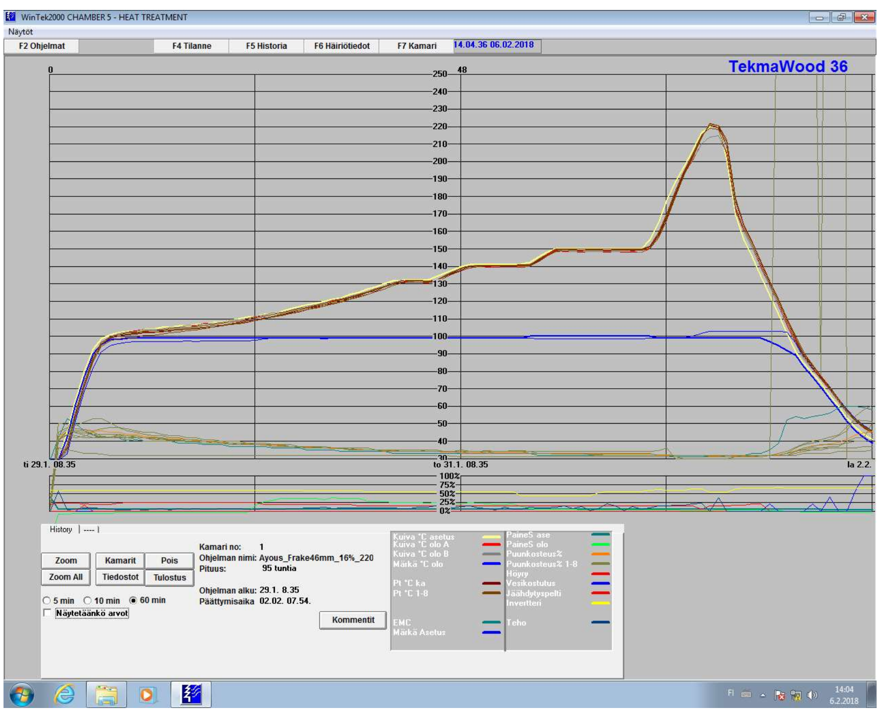


FIGURE 6. Program curve of the second batch

5.2 Preparing of the samples

Preparing of the samples started by straightening the material by planing. After that the planks were sawn down to specific dimensions for different tests. From each reference and treated plank there were two pieces made for the bending and dimensional stability tests and one piece for the rest of them. Test pieces were marked according to their original plank number and planed down to their accurate dimensions. In total, there were 720 test pieces.

5.3 Test conditions

The moisture content of the test pieces was not conditioned according to the standard requirements (12 %). They were tested in the moisture content they stabilized in the wood workshop. The moisture content of the treated test pieces was around 2 % and around 6 % with the reference pieces. The machine used for the tests was a Shimadzu AG-Xplus series with loading capacity up to 100 kN.

5.4 4-point bending

4-point bending tests were made according to the EN 408 standard and the global modulus of elasticity was tested together with the modulus of rupture. They were calculated with the following formulas (Formula 1 and Formula 2) where:

- Em,g is global modulus of elasticity
- fm is the modulus of rupture
- F is the load in newtons, a is the distance between the upper supports
- l is the distance between the lower supports
- $w_2 - w_1$ is the increment of deformation corresponding to $F_2 - F_1$ in millimetres
- $F_2 - F_1$ is an increment of load in newtons on the regression line with correlation coefficient of 0.99 or better
- b is the width of the test piece
- h is the height of the test piece
- G is the shear modulus, which is ignored in these calculations

FORMULA 1. Modulus of elasticity

$$E_{m,g} = \frac{3al^2 - 4a^3}{2bh^3(2\frac{w_2 - w_1}{F_2 - F_1} - \frac{6a}{5Gbh}}$$

FORMULA 2. Modulus of rupture

$$fm = \frac{3Fa}{bh^2}$$

Test pieces were 380 mm by length and 20 mm by width and thickness. Each test batch had 60 samples, which were bent until the maximum load was achieved and the material failure occurred. The supports were placed according to the test arrangement for global modulus of elasticity (Figure 7). The pressure was applied downwards from the upper support with the constant speed of 0.06 mm/s.

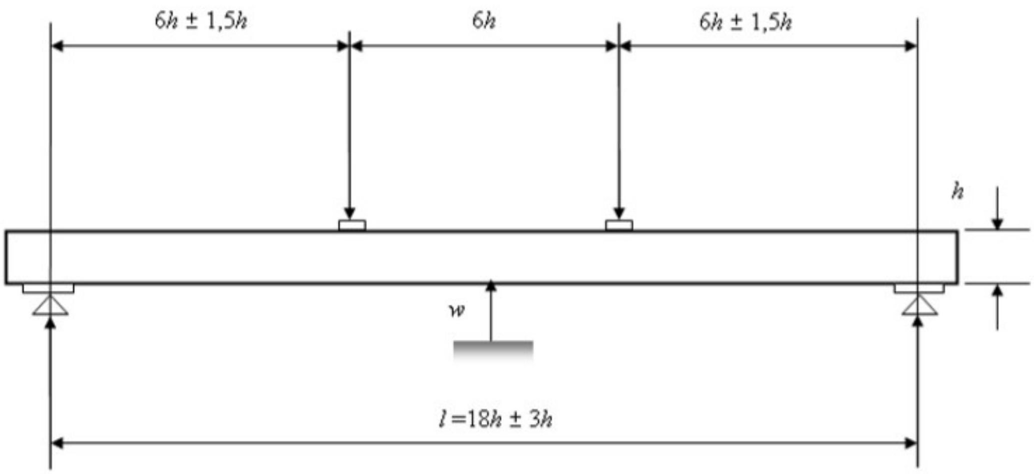
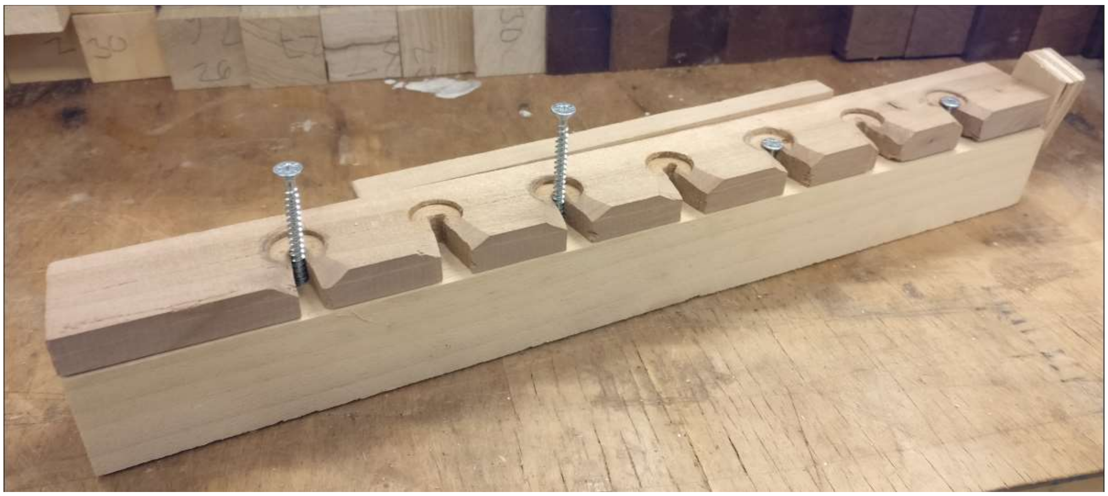


FIGURE 7. Test arrangements for global modulus of elasticity (EN 308)

5.5 Screw withdrawal

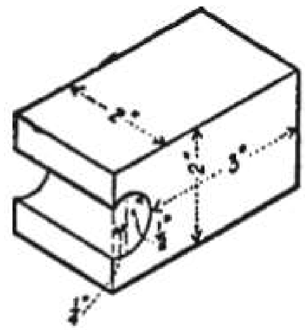
Screw withdrawal was performed according to the BGS-SKH 002 standard with slight adaptions. Used screws were Wurth 3.5*40 WUPOFAST Countersunk and fully galvanised screws with a PZ2 head. They match the requirements of the NEN-6562 standard. Screws were pulled straight out of the material in constant speed of 1 mm/s and the force necessary was measured in newtons. The test pieces were 350 mm long and 30 mm in width and height. The screws were fastened in pre-drilled holes of 2.4 mm diameter with an assembly tool that restricted the assembly depth to 28 mm (Picture 3). Seven screws were distributed evenly on radial and tangential cross sections with 35 mm distance in each test piece. At least 15 test pieces were tested for each test batch. That makes 420 screw withdrawals in total. The withdrawn screws were reused if there were no apparent defects.



PICTURE 3. The screw assembly tool in use.

5.6 Cleavage

Cleavage tests were performed with the ASTM D 143 standard in mind. To be able to do this test, it was necessary to make new test jigs for the machine. Using the drawings of the standard's own jig, a simplified version was machined from solid steel. It was possible to attach the new testing jig to the testing machine's own jaws. The test pieces (Figure 8) were different from the standard's regulations by their width, which was 28 mm for ayous and 40 with frake test pieces. During the test the stress load was applied upwards at a constant speed of 0.04 mm/s and the maximum force divided by the width of the test piece was calculated.



Metric Equivalents

in.	¼	½	2	3
mm	6	13	50	76

FIGURE 8. Cleavage test piece with and its dimensions (ASTM D 143)

5.7 Brinell hardness

Brinell hardness was tested according to the ISO 6506-1 standard. Although it is standard for metallic materials it is commonly used for wooden materials. The test was made using a steel ball with a diameter of 10 mm, which meets the requirements of the older version of this standard. The ball was pressed on the surface of the test piece with a force of 980 N. The indentation created by the ball was then measured horizontally and vertically using a loop that had scale of 0.1 mm engraved in its lens. The hardness was measured from the test pieces of the dimensional stability adsorption batch. The Brinell hardness was calculated with a formula (Formula 3) where:

- HBW is Brinell hardness
- F is test force in newtons
- D is diameter of the ball
- d is mean diameter of the indentation.

FORMULA 3. Brinell Hardness

$$HBW = 0{,}102 * \frac{2F}{\pi D^2 (1 - \sqrt{1 - \frac{d^2}{D^2}})}$$

5.8 Dimensional stability

Dimensional stability was tested according to the EN 318 standard. Dimensions of the test piece were 300 mm in length, 50 mm in width and 25 mm of thickness. Before going into the climate chamber the test pieces were weighed and marked from the required measurement points. For both adsorption and desorption test there was one piece from reference and treated planks. Half of the pieces went through the three-phase adsorption test. In the first step they were conditioned in 35 % of relative moisture content in the air. After stabilizing in the relative moisture content in air of 65 and 85 % of steps 2 and 3 the test pieces were measured for change in length and thickness. They were also weighed to calculate the equilibrium moisture content they acquired in each step. In desorption the same steps were performed in reversed order. The temperature in the climate chamber was 20 °C in both tests.

The dimensional changes were measured at an accuracy of 0.01 mm. The thickness was measured from three spots with Mitotoyos digital meter and the change in length was measured with a device that was built on the same manufacturer’s clock meter. Weights of the pieces were measured using Mettlers PM 4800 digital scale at an accuracy of 0.01 g. (Picture 4)

PICTURE 4. The used measuring equipment.

6 RESULTS

According to the results of the two treated batches, it seems possible to modify both species at 220 °C with stable results. The test results between the treatment batches are similar to a point that their results are not separated in the following chapters.

6.1 4-point bending

The results of the 4-point bending are clear. Both species had strongly decreased modulus of rupture. With ayous it had dropped down for 39.6 % and for frake 32.4 %. (Figure 9)

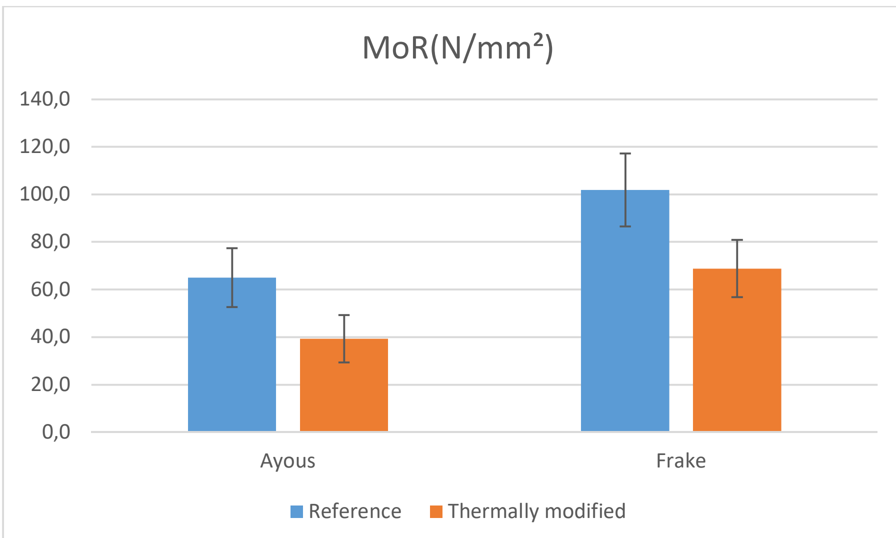


FIGURE 9. Mean modulus of rupture with the standard deviation lines.

The treatment had only a little impact on the modulus of elasticity of ayous decreasing it by 7.8 %. Frake’s modulus of elasticity had suffered more. It had decreased by 20.4 % (Figure10).

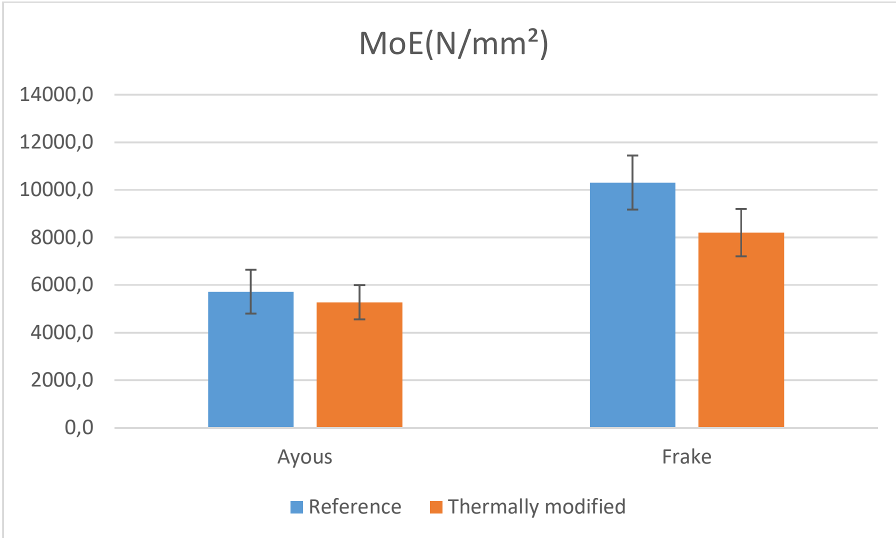


FIGURE 10. Mean modulus of elasticity with the standard deviation lines

Examining the breaking points of the treated test pieces shows that they are distinctly more brittle. While applying the testing load, treated specimens broke without showing any signs of imminent failure other than slight cracks just before shattering.

6.2 Screw withdrawal

Treatment had decreased the screw withdrawal strength especially with ayous. Thermally modified ayous held only 906.6 newtons, which is only half of the strength of its references. Frake lost 28 % of its screw withdrawal strength in the treatment. (Figure 11.)

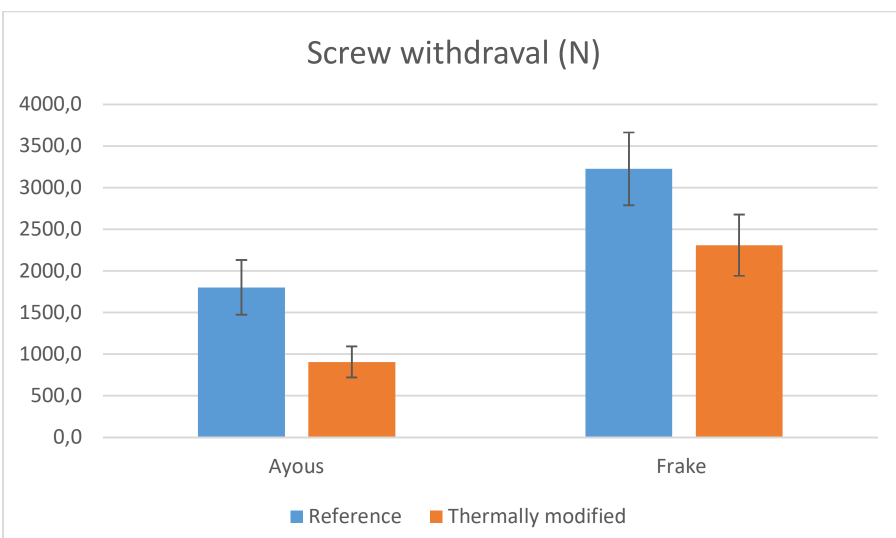


FIGURE 11. Screw withdrawal strength with the standard deviation lines

6.3 Cleavage

From the tested properties, thermal modification had the strongest negative effect on the cleavage strength. Both species lost half of their strength. More exactly, the cleavage strength of ayous decreased 53.2 % and frake's loss was 49,7 %. (Figure 12.)

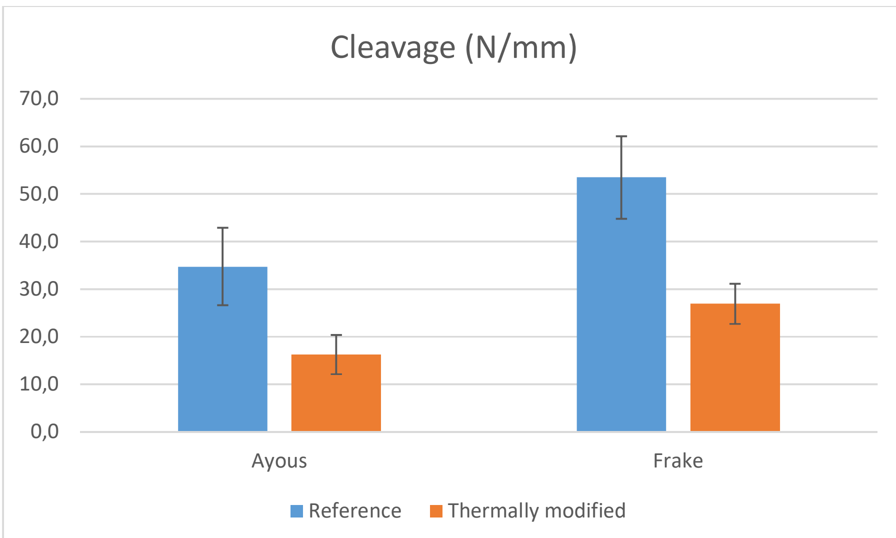


FIGURE 12. Mean cleavage strength with the standard deviation lines

6.4 Brinell hardness

The Brinell hardness has also decreased with both thermally modified woods. The drop in hardness was 44.4% for ayous and 23.5 % for frake (Figure 13). Measuring the surface hardness of ayous pushes the limits of the standard because of its softness. In 7 of the treated test pieces the load applying ball was buried deep in the wood material before the test force was reached. Thus the mean diameter of the dentation is too large in relation to the ball used to apply the load. With the references the relation of the indentation and the ball is 0.85/1 and 0.93/1 with the treated after eliminating the seven pieces that were proven to be too soft. The standard recommendations are between 0.24/1 and 0.60/1. Frake fits in the upper part of this recommendation.

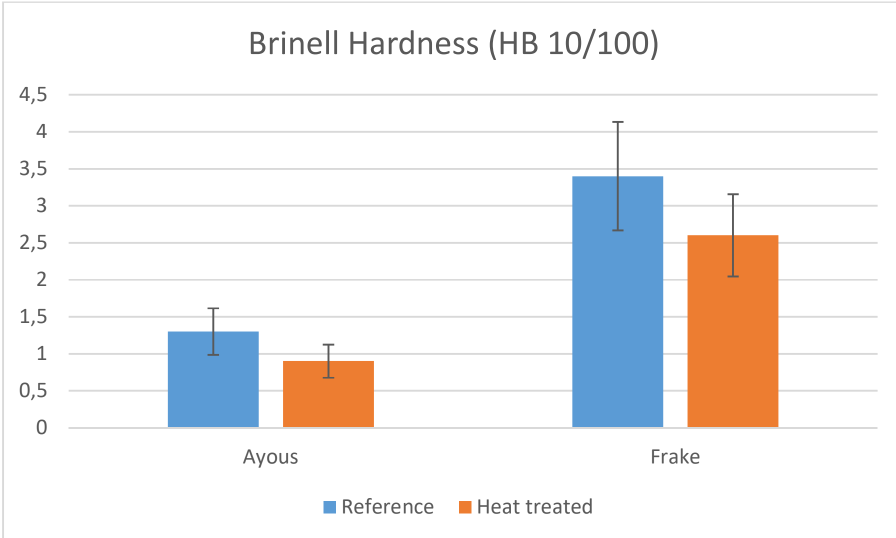


Figure 13. Mean Brinell hardness with the standard deviation lines

6.5 Dimensional stability

The results of change in length are varying. The results indicate that in the adsorption batch the treated frake had deformed more than its reference (Figure 14), which is an unexpected result. This makes me suspect that during the measurements of frake there must have been a calibration error in the length measuring equipment. This is a shame especially because of the promising results of its desorption batch where the deformation had decreased by 75 %. Ayous had decreased its deformation in adsorption by 16.7 % and 43.1% in desorption. The results for change in thickness are good and even. With ayous, thermal modification has decreased it by 65 % and 60 % for frake (Figure 15)

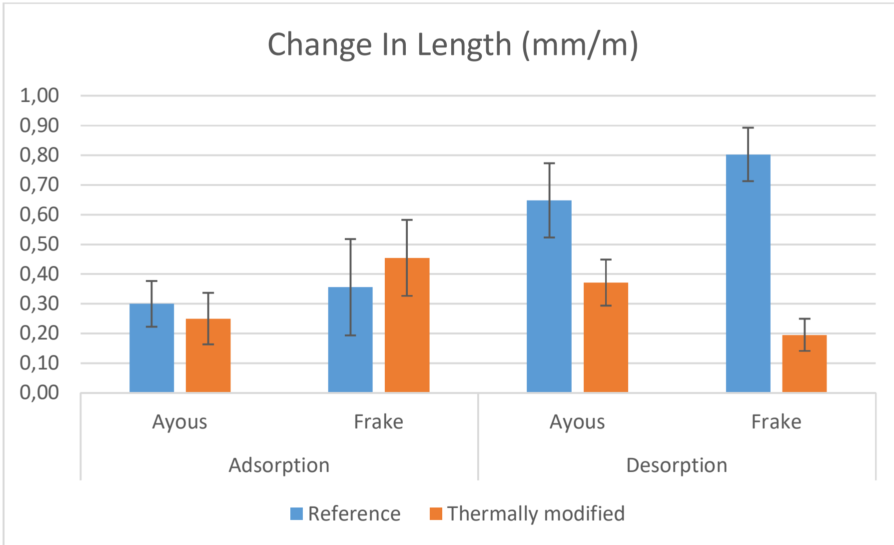


FIGURE 14. Mean change in length with the standard deviation lines

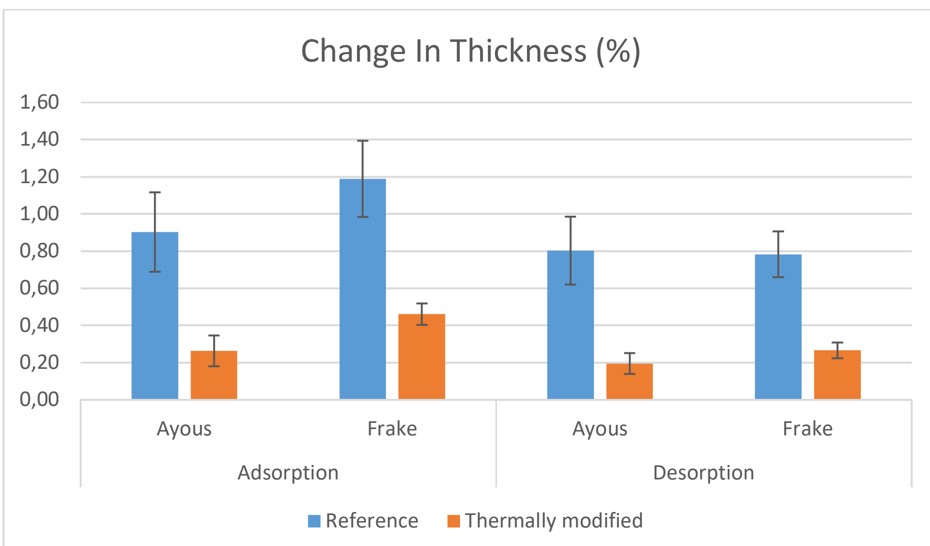


FIGURE 15. Mean change in thickness with the standard deviation lines

The decreased equilibrium moisture content is looking positive. It has dropped 66 % with ayous and 63 % on frake (Figure 16). This will make the wood material much more resistant against fungi.

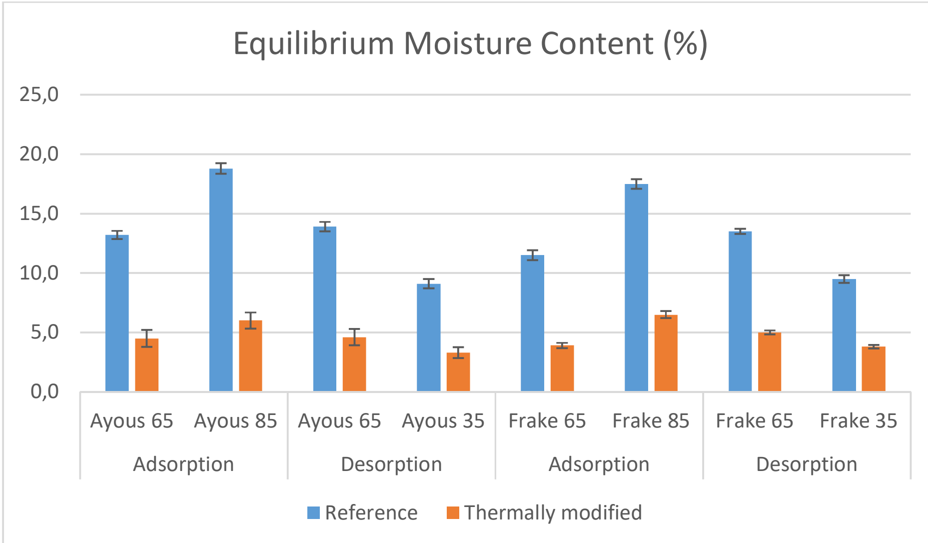


Figure 16. Mean equilibrium moisture content with the standard deviation lines

6.6 Density and weight loss

The loss of density was tolerable. For ayous the decrease was 9.05 % and for frake it was only 3.35 % (Figure 17).

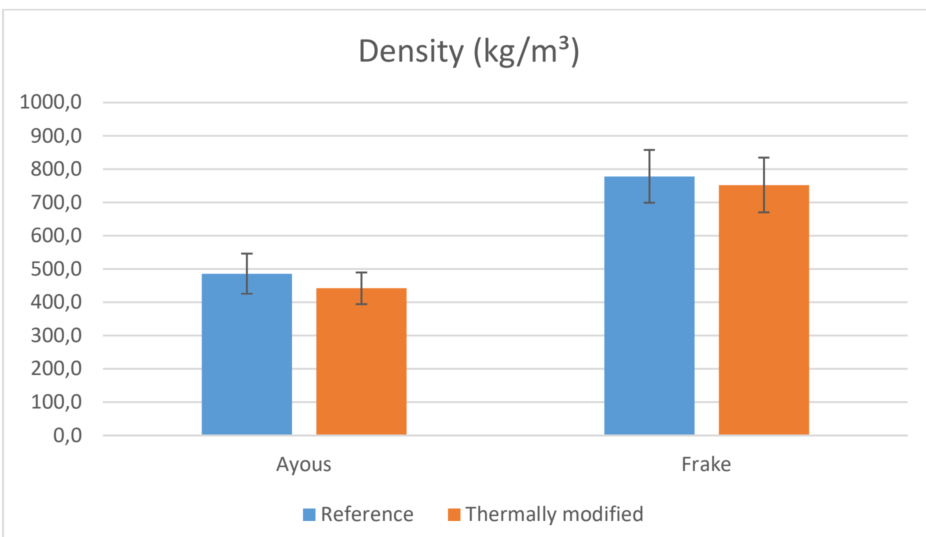


Figure 18. Mean density with the standard deviation lines

6.7 Appearance

After the treatment the colour of ayous and frake was remarkably darker (Picture 5) when examined visually by naked eye. The colour of ayous is light brown with a hint of yellow or pinkish colour stripes here and there. After the treatment it had changed to dark reddish brown.

The colour of Frake was greyish brown and it could have easily be mistaken to be oak. After the treatment its colour was dark brown that highlighting its grain pattern. The treated Frake also had a nice shine to its planed surface even without any surface treatment.

PICTURE 5. Thermally modified ayous (left) and frake (right) with their references

7 CONCLUSIONS

The goal of this thesis was to study the effects of the thermal modification process on frake and ayous and whether it was possible to duplicate the results in following treatments. The literature part gives the reader a good overview of the thermal modification process and the wood species used in the practical part.

The practical part is straightforward laboratory working without mentionable problems. It gives an overview of the performed thermal modification and the used testing methods.

The results were close to what was expected at the beginning. A significant decrease in equilibrium moisture content brought a positive impact on dimensional stability, and the reduced mechanical properties put some limitations on the end uses. In my opinion the trademark colour change of the thermal modification is an improvement with these materials, balancing the small discoloration in the materials. Especially frake has the look of a high-end furniture material.

Further research propositions

The density within the test planks seemed to vary depending on the test piece so further research in the weight loss in a manner where test pieces are weighed before and after the treatment could be productive.

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APPENDICES

APPENDIX 1

List of thermal modification batches.

Frake		
Board	Batch 1	Batch 2
1	X	
2	X	
3	X	
4		X
5		X
6		X
7	X	
8	X	
9	X	
10		X
11		X
12		X
13	X	
14	X	
15	X	
16		X
17		X
18		X
19	X	
20	X	
21	X	
22		X
23		X
24		X
25	X	
26	X	
27	X	
28	X	
29		X
30		X

Ayous		
Board	Batch 1	Batch 2
1		X
2		X
3		X
4		X
5	X	
6	X	
7		X
8		X
9	X	
10	X	
11		X
12		X
13	X	
14	X	
15		X
16		X
17	X	
18	X	
19		X
20		X
21	X	
22	X	
23		X
24		X
25	X	
26	X	
27	X	
28		X
29	X	
30	X	

APPENDIX 2

Test results from ayous on dimensional stability

ADSORPTION		**Cycle 2**		**20 C / 65% RH**	
Sample	**Weight**	**Length**	**Thickness**		
			1	2	3
	g	mm	mm	mm	mm
1	148,00	300,35	25,51	25,48	25,47
2	114,70	300,28	25,56	25,58	25,56
3	141,30	300,21	25,52	25,46	25,41
4	127,10	300,32	25,55	25,57	25,54
5	149,30	300,39	25,48	25,52	25,57
6	172,40	300,31	25,56	25,58	25,57
7	142,70	300,28	25,51	25,56	25,53
8	171,00	300,20	25,53	25,34	25,41
9	161,40	300,29	25,54	25,52	25,51
10	164,10	300,36	25,53	25,51	25,50
11	179,80	300,26	25,38	25,42	25,36
12	127,30	300,37	25,56	25,57	25,57
13	169,90	300,13	25,54	25,53	25,54
14	160,00	300,10	25,44	25,48	25,51
15	173,20	299,94	25,44	25,48	25,44
16	145,80	300,26	25,63	25,61	25,58
17	133,00	300,20	25,61	25,62	25,54
18	156,50	300,42	25,51	25,54	25,54
19	150,90	300,25	25,65	25,56	25,54
20	136,00	300,47	25,57	25,59	25,56
21	156,70	300,30	25,44	25,44	25,44
22	137,20	300,14	25,47	25,49	25,48
23	137,50	300,21	25,59	25,58	25,56
24	148,50	300,35	25,49	25,54	25,50
25	148,00	300,31	25,49	25,48	25,43
26	127,70	300,34	25,53	25,54	25,53
27	133,80	300,34	25,64	25,59	25,55
28	165,80	300,55	25,64	25,69	25,66
29	149,70	300,36	25,58	25,61	25,60
30	129,50	300,42	25,67	25,59	25,50

ADSORPTION		Cycle 3		20 C / 85% RH	
Sample	Weight	Length	Thickness		
			1	2	3
	g	mm	mm	mm	mm
1	154,10	300,42	25,75	25,73	25,71
2	119,50	300,38	25,76	25,78	25,76
3	148,30	300,31	25,83	25,78	25,73
4	132,80	300,42	25,74	25,75	25,71
5	156,30	300,45	25,78	25,78	25,86
6	180,10	300,40	25,79	25,79	25,77
7	149,20	300,39	25,68	25,75	25,70
8	179,00	300,28	25,59	25,59	25,65
9	168,50	300,39	25,76	25,76	25,73
10	171,60	300,45	25,86	25,86	25,81
11	188,50	300,43	25,68	25,71	25,67
12	132,50	300,45	25,80	25,78	25,80
13	176,60	300,22	25,76	25,74	25,69
14	167,20	300,16	25,73	25,78	25,80
15	180,90	300,01	25,69	25,77	25,69
16	152,80	300,35	25,93	25,94	25,85
17	139,60	300,30	25,77	25,81	25,71
18	162,70	300,52	25,72	25,70	25,72
19	157,70	300,33	25,72	25,71	25,68
20	141,90	300,53	25,77	25,78	25,73
21	164,10	300,40	25,67	25,67	25,66
22	143,10	300,22	25,72	25,73	25,74
23	143,20	300,27	25,86	25,84	25,81
24	153,40	300,42	25,64	25,66	25,64
25	154,40	300,40	25,78	25,75	25,73
26	133,00	300,42	25,77	25,80	25,76
27	139,70	300,45	25,89	25,87	25,81
28	173,80	300,66	25,86	25,92	25,86
29	156,20	300,43	25,73	25,78	25,77
30	135,00	300,55	25,94	25,87	25,76

Change in length	
Sample	Change
	mm/m
1	0,23
2	0,33
3	0,33
4	0,33
5	0,20
6	0,30
7	0,37
8	0,27
9	0,33
10	0,30
11	0,57
12	0,27
13	0,30
14	0,20
15	0,23
16	0,30
17	0,33
18	0,33
19	0,27
20	0,20
21	0,33
22	0,27
23	0,20
24	0,23
25	0,30
26	0,27
27	0,37
28	0,37
29	0,23
30	0,43
Average	**0,30**

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Change in thickness				
Sample	Change			
	1	2	3	Average
	%	%	%	%
1	0,94	0,98	0,94	0,95
2	0,78	0,78	0,78	0,78
3	1,21	1,26	1,26	1,24
4	0,74	0,70	0,67	0,70
5	1,18	1,02	1,13	1,11
6	0,90	0,82	0,78	0,83
7	0,67	0,74	0,67	0,69
8	0,24	0,99	0,94	0,72
9	0,86	0,94	0,86	0,89
10	1,29	1,37	1,22	1,29
11	1,18	1,14	1,22	1,18
12	0,94	0,82	0,90	0,89
13	0,86	0,82	0,59	0,76
14	1,14	1,18	1,14	1,15
15	0,98	1,14	0,98	1,03
16	1,17	1,29	1,06	1,17
17	0,62	0,74	0,67	0,68
18	0,82	0,63	0,70	0,72
19	0,27	0,59	0,55	0,47
20	0,78	0,74	0,67	0,73
21	0,90	0,90	0,86	0,89
22	0,98	0,94	1,02	0,98
23	1,06	1,02	0,98	1,02
24	0,59	0,47	0,55	0,54
25	1,14	1,06	1,18	1,13
26	0,94	1,02	0,90	0,95
27	0,98	1,09	1,02	1,03
28	0,86	0,90	0,78	0,84
29	0,59	0,66	0,66	0,64
30	1,05	1,09	1,02	1,06
			Average	**0,90**

Equilibrium moisture content		
Sample	EMC	
	65% RH	85% RH
	%	%
1	13,41	18,08
2	13,45	18,20
3	12,68	18,26
4	13,28	18,36
5	12,59	17,87
6	13,42	18,49
7	13,52	18,70
8	12,72	18,00
9	13,58	18,58
10	13,88	19,08
11	13,58	19,08
12	13,36	17,99
13	13,42	17,89
14	13,72	18,83
15	12,76	17,77
16	13,55	19,00
17	12,90	18,51
18	13,65	18,16
19	12,86	17,95
20	13,24	18,15
21	12,90	18,23
22	13,11	17,97
23	13,26	17,96
24	13,53	17,28
25	13,06	17,95
26	13,01	17,70
27	12,72	17,69
28	13,33	18,80
29	13,24	18,15
30	13,00	17,80
Average	**13,22**	**18,22**

DESORPTION		Cycle 2		20 C / 65% RH	
Sample	Weight	Length	Thickness		
			1	2	3
	g	mm	mm	mm	mm
1	121,51	300,21	25,60	25,57	25,55
2	103,83	300,24	25,59	25,56	25,54
3	156,22	300,30	25,66	25,59	25,55
4	122,16	300,42	25,59	25,62	25,59
5	154,85	300,41	25,55	25,62	25,73
6	167,09	300,00	25,56	25,53	25,55
7	147,04	300,26	25,54	25,56	25,54
8	183,97	300,34	25,64	25,63	25,70
9	143,99	300,13	25,68	25,63	25,59
10	154,02	300,24	25,61	25,57	25,57
11	176,43	300,27	25,50	25,51	25,49
12	104,73	300,20	25,50	25,51	25,55
13	149,27	300,20	25,57	25,56	25,58
14	148,37	300,08	25,64	25,54	25,52
15	177,36	300,20	25,57	25,57	25,55
16	135,13	300,30	25,65	25,59	25,61
17	128,56	300,25	25,56	25,59	25,60
18	160,08	300,15	25,58	25,53	25,52
19	155,31	300,23	25,55	25,54	25,52
20	145,64	300,25	25,64	25,65	25,63
21	155,10	300,25	25,49	25,48	25,52
22	138,76	300,28	25,65	25,61	25,60
23	132,13	300,31	25,62	25,61	25,63
24	138,49	300,35	25,61	25,62	25,62
25	161,77	300,18	25,55	25,53	25,61
26	123,49	300,27	25,65	25,62	25,60
27	135,36	300,38	25,70	25,74	25,67
28	169,47	300,44	25,72	25,73	25,69
29	153,52	300,30	25,63	25,65	25,52
30	126,12	300,28	25,75	25,68	25,64

DESORPTION		Cycle 3	20 C / 35% RH		
Sample	Weight	Length	Thickness		
			1	2	3
	g	mm	mm	mm	mm
1	115,63	300,00	25,33	25,31	25,27
2	99,26	300,04	25,38	25,36	25,36
3	149,59	300,13	25,39	25,38	25,31
4	116,90	300,16	25,45	25,51	25,48
5	148,13	300,25	25,31	25,38	25,46
6	159,59	299,85	25,39	25,35	25,36
7	140,20	299,94	25,39	25,39	25,36
8	176,59	300,16	25,39	25,41	25,47
9	137,49	299,96	25,44	25,41	25,39
10	147,47	300,04	25,32	25,33	25,33
11	169,43	300,04	25,25	25,27	25,25
12	100,54	300,03	25,32	25,34	25,37
13	142,87	300,03	25,35	25,35	25,38
14	141,61	299,90	25,34	25,25	25,26
15	170,52	300,00	25,37	25,38	25,39
16	129,21	300,10	25,42	25,32	25,37
17	122,91	300,00	25,40	25,48	25,52
18	154,31	299,99	25,42	25,39	25,36
19	148,78	300,05	25,41	25,40	25,38
20	139,78	300,07	25,46	25,49	25,49
21	148,00	300,07	25,32	25,30	25,34
22	132,87	300,09	25,39	25,36	25,36
23	125,98	300,15	25,32	25,35	25,36
24	133,42	300,15	25,43	25,45	25,46
25	155,55	300,03	25,30	25,29	25,38
26	118,74	300,08	25,44	25,39	25,38
27	130,17	300,21	25,48	25,52	25,46
28	162,42	300,18	25,54	25,52	25,51
29	147,43	300,09	25,40	25,50	25,47
30	120,94	300,09	25,43	25,46	25,48

Change in length	
Sample	Change
	mm/m
1	0,70
2	0,67
3	0,57
4	0,87
5	0,53
6	0,50
7	1,07
8	0,60
9	0,57
10	0,67
11	0,77
12	0,57
13	0,57
14	0,60
15	0,67
16	0,67
17	0,83
18	0,53
19	0,60
20	0,60
21	0,60
22	0,63
23	0,53
24	0,67
25	0,50
26	0,63
27	0,57
28	0,87
29	0,70
30	0,63
Average	**0,65**

Change in thickness				
Sample	Change			
	1	2	3	Average
	%	%	%	%
1	1,05	1,02	1,10	1,06
2	0,82	0,78	0,70	0,77
3	1,05	0,82	0,94	0,94
4	0,55	0,43	0,43	0,47
5	0,94	0,94	1,05	0,98
6	0,67	0,71	0,74	0,70
7	0,59	0,67	0,70	0,65
8	0,98	0,86	0,89	0,91
9	0,93	0,86	0,78	0,86
10	1,13	0,94	0,94	1,00
11	0,98	0,94	0,94	0,95
12	0,71	0,67	0,70	0,69
13	0,86	0,82	0,78	0,82
14	1,17	1,14	1,02	1,11
15	0,78	0,74	0,63	0,72
16	0,90	1,06	0,94	0,96
17	0,63	0,43	0,31	0,46
18	0,63	0,55	0,63	0,60
19	0,55	0,55	0,55	0,55
20	0,70	0,62	0,55	0,62
21	0,67	0,71	0,71	0,69
22	1,01	0,98	0,94	0,98
23	1,17	1,02	1,05	1,08
24	0,70	0,66	0,62	0,66
25	0,98	0,94	0,90	0,94
26	0,82	0,90	0,86	0,86
27	0,86	0,85	0,82	0,84
28	0,70	0,82	0,70	0,74
29	0,90	0,58	0,20	0,56
30	1,24	0,86	0,62	0,91
			Average	**0,8026**

Equilibrium moisture content		
Sample	EMC	
	65% RH	35% RH
	%	%
1	14,34	8,81
2	13,56	8,56
3	13,88	9,05
4	13,50	8,61
5	13,77	8,83
6	13,84	8,73
7	14,45	9,13
8	13,57	9,01
9	14,37	9,21
10	13,84	9,00
11	14,43	9,89
12	13,37	8,83
13	13,83	8,95
14	14,62	9,40
15	13,29	8,92
16	13,92	8,93
17	13,63	8,64
18	13,51	9,42
19	13,64	8,86
20	13,97	9,38
21	14,85	9,60
22	13,84	9,01
23	13,99	8,69
24	13,74	9,58
25	14,19	9,80
26	13,83	9,45
27	13,37	9,02
28	14,07	9,32
29	14,58	10,03
30	13,93	9,25
Average	**13,92**	**9,13**

APPENDIX 3

Test results of dimensional stability for thermally modified ayous

ADSORPTION		Cycle 2		20 C / 65% RH	
Sample	**Weight**	**Length**	**Thickness**		
			1	2	3
	g	mm	mm	mm	mm
1	106,70	300,38	25,09	25,09	25,09
2	109,20	300,26	25,00	25,05	25,03
3	112,70	300,25	25,02	25,04	25,00
4	109,80	300,22	25,00	25,04	25,03
5	126,60	300,32	25,02	25,05	25,07
6	140,00	300,21	24,96	24,97	24,95
7	118,90	300,23	25,01	24,98	24,98
8	130,10	300,28	24,97	25,02	25,06
9	135,10	300,29	25,00	25,02	25,02
10	134,10	300,32	25,02	25,04	25,09
11	125,40	300,45	25,02	25,07	25,05
12	89,00	299,70	25,08	25,09	25,05
13	142,80	300,32	25,08	25,08	25,04
14	127,70	300,36	25,04	25,05	25,04
15	135,30	300,33	25,05	25,06	25,06
16	126,40	300,31	25,00	25,01	25,00
17	112,50	300,28	25,03	25,02	25,01
18	132,20	300,31	25,04	25,01	25,01
19	127,20	299,89	24,99	25,02	25,01
20	116,60	300,16	24,99	25,01	25,00
21	130,00	300,45	25,05	25,03	25,04
22	122,40	300,37	25,03	25,06	25,07
23	109,00	299,53	24,99	24,98	25,00
24	109,00	300,15	25,02	25,02	25,00
25	122,00	299,85	25,04	25,08	25,07
26	116,50	300,38	25,05	25,05	25,03
27	120,90	300,38	25,03	25,05	25,04
28	137,80	300,39	25,01	25,01	25,04
29	133,80	300,26	25,00	25,07	25,03
30	102,10	300,36	24,98	25,05	25,09

ADSORPTION		Cycle 3		20 C / 85% RH	
Sample	Weight	Length	Thickness		
			1	2	3
	g	mm	mm	mm	mm
1	108,50	300,43	25,17	25,18	25,17
2	110,90	300,33	25,07	25,10	25,09
3	114,10	300,34	25,08	25,09	25,07
4	110,80	300,32	25,03	25,06	25,05
5	128,70	300,40	25,10	25,13	25,16
6	142,30	300,27	25,02	25,05	25,04
7	120,20	300,32	25,07	25,03	25,02
8	131,80	300,33	25,02	25,06	25,11
9	137,10	300,37	25,08	25,11	25,10
10	136,00	300,43	25,11	25,12	25,17
11	127,30	300,56	25,09	25,13	25,13
12	90,40	299,73	25,16	25,22	25,16
13	145,00	300,38	25,14	25,15	25,12
14	129,90	300,42	25,14	25,14	25,14
15	137,50	300,40	25,14	25,16	25,17
16	128,00	300,36	25,05	25,07	25,06
17	114,10	300,39	25,05	25,06	25,06
18	134,10	300,38	25,08	25,06	25,06
19	129,00	299,94	25,04	25,07	25,06
20	117,90	300,20	25,03	25,05	25,05
21	131,90	300,51	25,11	25,10	25,10
22	124,30	300,42	25,10	25,13	25,14
23	110,30	299,57	25,05	25,04	25,06
24	110,20	300,24	25,06	25,06	25,04
25	123,70	299,95	25,11	25,15	25,15
26	118,60	300,50	25,16	25,14	25,12
27	122,80	300,45	25,10	25,12	25,11
28	139,70	300,52	25,07	25,06	25,10
29	135,60	300,33	25,04	25,11	25,07
30	103,70	300,45	25,06	25,13	25,17

Change in length	
Sample	Change
	mm/m
1	0,17
2	0,23
3	0,30
4	0,33
5	0,27
6	0,20
7	0,30
8	0,17
9	0,27
10	0,37
11	0,37
12	0,10
13	0,20
14	0,20
15	0,23
16	0,17
17	0,37
18	0,23
19	0,17
20	0,13
21	0,20
22	0,17
23	0,13
24	0,30
25	0,33
26	0,40
27	0,23
28	0,43
29	0,23
30	0,30
Average	**0,25**

Change in thickness				
Sample	Change			
	1	2	3	Average
	%	%	%	%
1	0,32	0,36	0,32	0,33
2	0,28	0,20	0,24	0,24
3	0,24	0,20	0,28	0,24
4	0,12	0,08	0,08	0,09
5	0,32	0,32	0,36	0,33
6	0,24	0,32	0,36	0,31
7	0,24	0,20	0,16	0,20
8	0,20	0,16	0,20	0,19
9	0,32	0,36	0,32	0,33
10	0,36	0,32	0,32	0,33
11	0,28	0,24	0,32	0,28
12	0,32	0,52	0,44	0,43
13	0,24	0,28	0,32	0,28
14	0,40	0,36	0,40	0,39
15	0,36	0,40	0,44	0,40
16	0,20	0,24	0,24	0,23
17	0,08	0,16	0,20	0,15
18	0,16	0,20	0,20	0,19
19	0,20	0,20	0,20	0,20
20	0,16	0,16	0,20	0,17
21	0,24	0,28	0,24	0,25
22	0,28	0,28	0,28	0,28
23	0,24	0,24	0,24	0,24
24	0,16	0,16	0,16	0,16
25	0,28	0,28	0,32	0,29
26	0,44	0,36	0,36	0,39
27	0,28	0,28	0,28	0,28
28	0,24	0,20	0,24	0,23
29	0,16	0,16	0,16	0,16
30	0,32	0,32	0,32	0,32
			Average	**0,26**

Equilibrium moisture content		
Sample	EMC	
	65% RH	85% RH
	%	%
1	3,59	5,34
2	3,90	5,52
3	4,26	5,55
4	6,19	7,16
5	4,11	5,84
6	5,82	7,56
7	4,67	5,81
8	3,91	5,27
9	3,84	5,38
10	3,31	4,78
11	4,50	6,08
12	4,71	6,35
13	5,54	7,17
14	4,42	6,21
15	4,40	6,10
16	4,81	6,14
17	3,88	5,36
18	3,69	5,18
19	5,65	7,14
20	4,86	6,03
21	4,33	5,86
22	4,44	6,06
23	5,83	7,09
24	4,61	5,76
25	4,36	5,82
26	4,02	5,89
27	3,96	5,59
28	3,92	5,35
29	4,69	6,10
30	4,93	6,58
Average	**4,50**	**6,00**

DESORPTION		Cycle 2		20 C / 65% RH	
Sample	**Weight**	**Length**	**Thickness**		
			1	2	3
	g	mm	mm	mm	mm
1	123,18	300,43	25,09	25,12	25,11
2	99,66	300,25	25,03	25,07	25,04
3	118,77	300,27	25,11	25,10	25,08
4	103,81	300,13	25,02	25,02	25,02
5	125,88	300,26	25,05	25,07	25,12
6	141,10	300,22	25,01	25,00	25,01
7	122,13	300,27	25,02	25,02	24,98
8	142,36	300,30	25,03	25,05	25,12
9	119,08	300,30	25,06	25,06	25,05
10	135,37	300,46	25,06	25,09	25,13
11	134,92	300,55	25,08	25,13	25,10
12	107,03	299,73	25,06	25,07	25,05
13	152,18	300,24	25,06	25,07	25,05
14	121,13	300,33	25,13	25,09	25,06
15	148,22	300,37	25,13	25,11	25,12
16	123,93	300,34	25,06	25,05	25,03
17	110,18	300,39	25,06	25,12	25,08
18	146,80	300,36	25,07	25,05	25,06
19	130,16	299,88	24,98	25,01	25,00
20	114,47	300,14	25,02	25,01	25,02
21	128,49	300,42	25,06	25,10	25,08
22	123,97	300,38	25,08	25,11	25,13
23	112,90	299,60	24,98	25,03	25,02
24	114,40	300,25	25,04	25,04	25,03
25	125,98	299,80	25,06	25,11	25,08
26	116,47	300,41	25,10	25,10	25,10
27	122,26	300,48	25,08	25,08	25,07
28	136,35	300,41	25,05	25,04	25,06
29	132,13	300,28	25,04	25,03	25,02
30	97,08	300,35	25,03	25,08	25,07

DESORPTION		Cycle 3	20 C / 35% RH		
Sample	Weight	Length	Thickness		
			1	2	3
	g	mm	mm	mm	mm
1	121,88	300,35	25,07	25,08	25,05
2	98,47	300,13	24,98	25,02	24,99
3	117,59	300,17	25,06	25,06	25,03
4	102,14	299,99	24,95	24,97	24,97
5	124,22	300,16	24,98	25,01	25,05
6	138,26	300,10	24,91	24,93	24,94
7	120,40	300,13	24,96	24,97	24,92
8	140,70	300,21	24,97	25,00	25,07
9	117,76	300,20	25,02	25,03	25,00
10	133,76	300,35	25,02	25,06	25,09
11	133,71	300,45	25,05	25,10	25,07
12	105,78	299,63	25,01	25,03	25,01
13	150,14	300,11	24,99	25,01	24,99
14	119,64	300,20	25,07	25,04	25,01
15	146,69	300,26	25,06	25,07	25,07
16	121,98	300,25	25,00	25,00	24,97
17	108,86	300,27	25,01	25,08	25,05
18	145,35	300,28	25,02	25,03	25,03
19	128,25	299,75	24,94	24,96	24,94
20	112,93	300,04	24,97	24,97	24,96
21	126,84	300,31	25,02	25,06	25,04
22	122,15	300,28	25,02	25,05	25,06
23	111,38	299,50	24,93	24,97	24,98
24	113,05	300,15	25,01	25,00	24,98
25	124,65	299,69	25,02	25,06	25,03
26	115,25	300,33	25,06	25,06	25,05
27	120,82	300,38	25,02	25,03	25,03
28	134,85	300,26	25,01	25,00	25,02
29	130,76	300,17	25,01	25,00	24,99
30	95,71	300,16	25,00	25,03	24,96

Change in length	
Sample	Change
	mm/m
1	0,27
2	0,40
3	0,33
4	0,47
5	0,33
6	0,40
7	0,47
8	0,30
9	0,33
10	0,37
11	0,33
12	0,33
13	0,43
14	0,43
15	0,37
16	0,30
17	0,40
18	0,27
19	0,43
20	0,33
21	0,37
22	0,33
23	0,33
24	0,33
25	0,37
26	0,27
27	0,33
28	0,50
29	0,37
30	0,63
Average	**0,37**

Change in thickness				
Sample	**Change**			
	1	2	3	Average
	%	%	%	%
1	0,08	0,16	0,24	0,16
2	0,20	0,20	0,20	0,20
3	0,20	0,16	0,20	0,19
4	0,28	0,20	0,20	0,23
5	0,28	0,24	0,28	0,27
6	0,40	0,28	0,28	0,32
7	0,24	0,20	0,24	0,23
8	0,24	0,20	0,20	0,21
9	0,16	0,12	0,20	0,16
10	0,16	0,12	0,16	0,15
11	0,12	0,12	0,12	0,12
12	0,20	0,16	0,16	0,17
13	0,28	0,24	0,24	0,25
14	0,24	0,20	0,20	0,21
15	0,28	0,16	0,20	0,21
16	0,24	0,20	0,24	0,23
17	0,20	0,16	0,12	0,16
18	0,20	0,08	0,12	0,13
19	0,16	0,20	0,24	0,20
20	0,20	0,16	0,24	0,20
21	0,16	0,16	0,16	0,16
22	0,24	0,24	0,28	0,25
23	-0,12	0,12	0,16	0,05
24	0,44	0,28	0,20	0,31
25	0,16	0,20	0,20	0,19
26	0,16	0,16	0,20	0,17
27	0,24	0,20	0,16	0,20
28	0,16	0,16	0,16	0,16
29	0,12	0,12	0,12	0,12
30	0,12	0,20	0,44	0,25
			Average	**0,20**

Equilibrium moisture content		
Sample	**EMC**	
	65% RH	35% RH
	%	%
1	3,83	2,73
2	4,13	2,88
3	3,77	2,73
4	5,73	4,03
5	4,44	3,06
6	6,53	4,39
7	5,04	3,55
8	4,03	2,81
9	3,95	2,80
10	4,53	3,29
11	3,81	2,88
12	4,00	2,79
13	4,94	3,53
14	4,30	3,01
15	4,15	3,07
16	5,60	3,94
17	4,46	3,20
18	4,00	2,98
19	5,56	4,01
20	5,08	3,66
21	4,63	3,28
22	5,09	3,54
23	5,18	3,76
24	4,60	3,36
25	4,38	3,28
26	4,56	3,47
27	4,77	3,54
28	4,24	3,09
29	4,24	3,16
30	5,75	4,26
Average	**4,64**	**3,34**

APPENDIX 4

Test results of dimensional stability for frake

ADSORPTION		Cycle 2	20 C / 65% RH		
Sample	**Weight**	**Length**	**Thickness**		
			1	2	3
	g	mm	mm	mm	mm
1	241,10	300,75	25,33	25,29	25,26
2	240,10	300,79	25,30	25,25	25,23
3	233,10	300,76	25,35	25,39	25,33
4	223,30	300,82	25,20	25,26	25,27
5	219,80	300,70	25,26	25,29	25,29
6	234,70	300,66	25,27	25,26	25,23
7	191,50	300,80	25,26	25,31	25,27
8	276,20	300,64	25,32	25,19	25,21
9	236,20	300,74	25,26	25,29	25,26
10	234,50	300,63	25,30	25,26	25,22
11	213,30	300,83	25,33	25,30	25,24
12	218,10	300,65	25,22	25,26	25,32
13	234,20	300,73	25,28	25,27	25,27
14	207,90	300,77	25,21	25,22	25,21
15	207,30	300,74	25,23	25,24	25,25
16	249,20	300,53	25,25	25,28	25,32
17	276,30	300,58	25,31	25,21	25,25
18	200,80	300,74	25,17	25,25	25,14
19	240,60	300,51	25,14	25,22	25,25
20	244,40	300,61	25,17	25,19	25,26
21	215,00	300,66	25,21	25,27	25,29
22	213,50	300,42	25,25	25,20	25,08
23	241,90	300,61	25,27	25,22	25,23
24	270,50	300,82	25,12	25,24	25,28
25	284,20	300,79	25,30	25,33	25,26
26	235,40	300,72	25,33	25,33	25,33
27	229,80	300,75	25,27	25,32	25,27
28	209,30	300,75	25,27	25,28	25,23
29	244,70	300,70	25,35	25,37	25,31
30	204,30	300,78	25,29	25,32	25,25

ADSORPTION		Cycle 3	20 C / 85% RH		
Sample	Weight	Length	Thickness		
			1	2	3
	g	mm	mm	mm	mm
1	255,10	300,92	25,65	25,63	25,66
2	253,60	300,84	25,62	25,62	25,60
3	244,70	300,81	25,70	25,75	25,69
4	235,30	300,91	25,51	25,58	25,59
5	230,40	300,78	25,53	25,55	25,57
6	246,30	300,81	25,58	25,57	25,57
7	202,80	300,92	25,49	25,53	25,51
8	291,20	300,78	25,69	25,58	25,56
9	248,30	300,82	25,52	25,59	25,70
10	245,10	300,74	25,60	25,55	25,50
11	224,60	300,94	25,62	25,57	25,54
12	227,50	300,73	25,47	25,52	25,62
13	246,60	300,79	25,61	25,64	25,62
14	218,30	300,90	25,45	25,47	25,44
15	217,30	300,88	25,45	25,46	25,50
16	262,00	300,61	25,55	25,61	25,66
17	289,90	300,80	25,68	25,49	25,53
18	210,40	300,82	25,44	25,51	25,45
19	251,20	300,58	25,43	25,49	25,48
20	255,10	300,68	25,49	25,53	25,58
21	224,40	300,72	25,43	25,54	25,55
22	222,30	300,50	25,48	25,44	25,32
23	255,10	300,74	25,61	25,56	25,57
24	282,10	300,85	25,46	25,50	25,58
25	300,00	301,02	25,72	25,74	25,69
26	247,30	300,84	25,67	25,66	25,65
27	241,90	300,90	25,59	25,64	25,61
28	220,10	300,88	25,54	25,55	25,49
29	256,70	300,85	25,63	25,66	25,62
30	211,10	300,83	25,46	25,48	25,44

Change in length	
Sample	Change
	mm/m
1	0,57
2	0,17
3	0,17
4	0,30
5	0,27
6	0,50
7	0,40
8	0,47
9	0,27
10	0,37
11	0,37
12	0,27
13	0,20
14	0,43
15	0,47
16	0,27
17	0,73
18	0,27
19	0,23
20	0,23
21	0,20
22	0,27
23	0,43
24	0,10
25	0,76
26	0,40
27	0,50
28	0,43
29	0,50
30	0,17
Average	**0,36**

Change in thickness				
Sample	**Change**			
	1	2	3	Average
	%	%	%	%
1	1,26	1,34	1,58	1,40
2	1,26	1,47	1,47	1,40
3	1,38	1,42	1,42	1,41
4	1,23	1,27	1,27	1,25
5	1,07	1,03	1,11	1,07
6	1,23	1,23	1,35	1,27
7	0,91	0,87	0,95	0,91
8	1,46	1,55	1,39	1,47
9	1,03	1,19	1,74	1,32
10	1,19	1,15	1,11	1,15
11	1,14	1,07	1,19	1,13
12	0,99	1,03	1,18	1,07
13	1,31	1,46	1,39	1,38
14	0,95	0,99	0,91	0,95
15	0,87	0,87	0,99	0,91
16	1,19	1,31	1,34	1,28
17	1,46	1,11	1,11	1,23
18	1,07	1,03	1,23	1,11
19	1,15	1,07	0,91	1,05
20	1,27	1,35	1,27	1,30
21	0,87	1,07	1,03	0,99
22	0,91	0,95	0,96	0,94
23	1,35	1,35	1,35	1,35
24	1,35	1,03	1,19	1,19
25	1,66	1,62	1,70	1,66
26	1,34	1,30	1,26	1,30
27	1,27	1,26	1,35	1,29
28	1,07	1,07	1,03	1,06
29	1,10	1,14	1,22	1,16
30	0,67	0,63	0,75	0,69
			Average	**1,19**

Equilibrium moisture content		
Sample	**EMC**	
	65% RH	85% RH
	%	%
1	11,21	17,67
2	11,16	17,41
3	12,07	17,64
4	11,54	17,53
5	11,01	16,36
6	12,14	17,68
7	11,60	18,18
8	11,01	17,04
9	11,26	16,96
10	12,25	17,33
11	11,15	17,04
12	11,79	16,61
13	11,63	17,54
14	11,71	17,30
15	11,87	17,27
16	11,35	17,07
17	11,41	16,90
18	11,68	17,02
19	11,96	16,89
20	12,06	16,96
21	11,98	16,88
22	12,43	17,06
23	11,22	17,29
24	12,01	16,81
25	11,10	17,28
26	11,94	17,59
27	11,39	17,26
28	11,21	16,95
29	11,58	17,05
30	12,50	16,24
Average	**11,64**	**17,16**

DESORPTION		Cycle 2	20 C / 65% RH		
Sample	Weight	Length	Thickness		
			1	2	3
	g	mm	mm	mm	mm
1	233,64	300,67	25,51	25,51	25,32
2	241,74	300,92	25,57	25,58	25,55
3	232,54	300,65	25,45	25,37	25,32
4	232,84	300,78	25,44	25,39	25,39
5	216,41	300,80	25,51	25,42	25,43
6	227,90	300,88	25,40	25,40	25,33
7	210,00	300,79	25,53	25,50	25,46
8	292,70	300,71	25,33	25,38	25,37
9	246,64	300,68	25,51	25,47	25,46
10	236,34	300,78	25,22	25,26	25,38
11	210,12	300,85	25,28	25,25	25,39
12	226,54	300,53	25,49	25,43	25,40
13	230,97	300,77	25,33	25,37	25,50
14	207,34	300,79	25,30	25,32	25,35
15	217,00	300,78	25,42	25,44	25,47
16	255,41	300,76	25,45	25,44	25,38
17	288,25	300,77	25,52	25,47	25,42
18	199,14	300,85	25,31	25,29	25,32
19	236,42	300,66	25,33	25,34	25,35
20	251,29	300,63	25,29	25,30	25,33
21	213,86	300,70	25,40	25,40	25,33
22	206,35	300,70	25,30	25,35	25,39
23	240,88	300,54	25,42	25,34	25,43
24	254,82	300,78	25,16	25,27	25,37
25	291,53	300,77	25,52	25,50	25,45
26	242,04	300,70	25,46	25,43	25,36
27	240,66	300,82	25,43	25,38	25,36
28	211,89	300,89	25,37	25,40	25,39
29	237,36	300,84	25,39	25,31	25,28
30	209,61	300,80	25,38	25,33	25,40

DESORPTION		Cycle 3		20 C / 35% RH	
Sample	Weight	Length	Thickness		
			1	2	3
	g	mm	mm	mm	mm
1	223,96	300,50	25,31	25,31	25,27
2	232,17	300,78	25,31	25,31	25,27
3	223,34	300,50	25,20	25,13	25,09
4	223,08	300,62	25,17	25,16	25,14
5	208,68	300,65	25,29	25,23	25,21
6	219,69	300,72	25,19	25,22	25,13
7	201,37	300,62	25,30	25,25	25,25
8	282,50	300,46	25,14	25,13	25,13
9	237,62	300,48	25,22	25,25	25,28
10	227,82	300,61	25,02	25,07	25,16
11	202,51	300,69	25,07	25,08	25,20
12	218,95	300,40	25,29	25,26	25,22
13	222,66	300,60	25,14	25,18	25,30
14	199,67	300,63	25,13	25,16	25,18
15	208,90	300,60	25,23	25,23	25,27
16	246,65	300,64	25,26	25,22	25,17
17	278,84	300,60	25,30	25,26	25,19
18	192,16	300,69	25,14	25,13	25,13
19	228,24	300,47	25,15	25,12	25,15
20	242,66	300,45	25,06	25,07	25,09
21	206,74	300,58	25,25	25,21	25,16
22	199,12	300,55	25,15	25,18	25,19
23	232,57	300,42	25,21	25,16	25,22
24	247,68	300,64	25,00	25,12	25,18
25	281,88	300,57	25,33	25,25	25,21
26	234,64	300,54	25,33	25,25	25,20
27	233,31	300,65	25,26	25,18	25,17
28	205,16	300,75	25,22	25,25	25,24
29	229,01	300,70	25,17	25,10	25,08
30	203,38	300,64	25,22	25,21	25,24

Change in length	
Sample	Change
	mm/m
1	0,57
2	0,47
3	0,50
4	0,53
5	0,50
6	0,53
7	0,57
8	0,83
9	0,67
10	0,57
11	0,53
12	0,43
13	0,57
14	0,53
15	0,60
16	0,40
17	0,57
18	0,53
19	0,63
20	0,60
21	0,40
22	0,50
23	0,40
24	0,47
25	0,66
26	0,53
27	0,57
28	0,47
29	0,47
30	0,53
Average	**0,54**

Change in thickness				
Sample	**Change**			
	1	2	3	Average
	%	%	%	%
1	0,78	0,78	0,20	0,59
2	1,02	1,06	1,10	1,06
3	0,98	0,95	0,91	0,95
4	1,06	0,91	0,98	0,98
5	0,86	0,75	0,87	0,82
6	0,83	0,71	0,79	0,78
7	0,90	0,98	0,82	0,90
8	0,75	0,99	0,95	0,89
9	1,14	0,86	0,71	0,90
10	0,79	0,75	0,87	0,80
11	0,83	0,67	0,75	0,75
12	0,78	0,67	0,71	0,72
13	0,75	0,75	0,78	0,76
14	0,67	0,63	0,67	0,66
15	0,75	0,83	0,79	0,79
16	0,75	0,86	0,83	0,81
17	0,86	0,82	0,90	0,86
18	0,67	0,63	0,75	0,68
19	0,71	0,87	0,79	0,79
20	0,91	0,91	0,95	0,92
21	0,59	0,75	0,67	0,67
22	0,59	0,67	0,79	0,68
23	0,83	0,71	0,83	0,79
24	0,64	0,59	0,75	0,66
25	0,74	0,98	0,94	0,89
26	0,51	0,71	0,63	0,62
27	0,67	0,79	0,75	0,74
28	0,59	0,59	0,59	0,59
29	0,87	0,83	0,79	0,83
30	0,63	0,47	0,63	0,58
			Average	**0,78**

Equilibrium moisture content		
Sample	**EMC**	
	65% RH	35% RH
	%	%
1	13,69	8,98
2	13,69	9,19
3	13,88	9,37
4	13,67	8,91
5	13,44	9,39
6	13,65	9,55
7	13,92	9,24
8	13,09	9,15
9	13,28	9,14
10	13,65	9,56
11	13,37	9,26
12	13,07	9,28
13	13,81	9,71
14	13,54	9,34
15	13,43	9,20
16	13,32	9,43
17	13,35	9,65
18	13,44	9,46
19	13,29	9,37
20	13,44	9,55
21	13,35	9,57
22	13,36	9,39
23	13,55	9,63
24	13,38	10,20
25	13,48	9,73
26	13,65	10,18
27	13,52	10,05
28	13,18	9,58
29	13,68	9,68
30	13,35	9,98
Average	**13,48**	**9,49**

APPENDIX 5

Test results of dimensional stability for thermally modified frake

ADSORPTION		**Cycle 2**	**20 C / 65% RH**		
Sample	**Weight**	**Length**	**Thickness**		
			1	2	3
	g	mm	mm	mm	mm
1	220,60	300,03	24,90	25,01	25,10
2	208,90	300,09	25,35	25,37	25,35
3	200,08	300,13	25,43	25,39	25,35
4	204,10	300,10	25,21	25,19	25,17
5	192,70	300,10	25,38	25,39	25,38
6	225,50	299,81	24,99	25,03	25,04
7	174,80	300,09	25,30	25,35	25,34
8	256,80	300,09	25,39	25,41	25,30
9	205,10	300,11	25,43	25,43	25,35
10	211,00	300,23	25,38	25,39	25,41
11	187,00	300,13	25,43	25,44	25,38
12	197,60	300,12	25,41	25,41	25,35
13	202,90	300,18	25,35	25,37	25,36
14	195,90	300,21	25,09	25,16	25,13
15	204,00	300,10	25,16	25,22	25,21
16	204,50	300,25	25,35	25,39	25,34
17	254,50	299,93	25,34	25,39	25,38
18	173,80	300,15	25,42	25,43	25,40
19	198,00	300,04	25,44	25,45	25,36
20	223,20	300,07	25,32	25,30	25,28
21	198,00	300,14	25,39	25,30	25,12
22	204,70	300,16	25,38	25,42	25,40
23	209,30	300,12	25,42	25,42	25,39
24	229,10	300,02	25,39	25,38	25,33
25	242,80	299,98	25,36	25,41	25,43
26	183,80	300,10	25,25	25,27	25,27
27	213,00	300,11	25,40	25,43	25,42
28	182,00	300,15	25,38	25,31	25,19
29	218,30	300,08	25,35	25,36	25,32
30	178,70	300,07	25,11	25,15	25,21

ADSORPTION		Cycle 3	20 C / 85% RH		
Sample	Weight	Length	Thickness		
			1	2	3
	g	mm	mm	mm	mm
1	225,90	300,20	25,03	25,13	25,20
2	214,10	300,23	25,47	25,49	25,46
3	205,50	300,28	25,51	25,49	25,48
4	209,50	300,24	25,34	25,31	25,31
5	197,70	300,23	25,48	25,50	25,49
6	231,20	299,92	25,11	25,16	25,16
7	179,20	300,20	25,40	25,44	25,43
8	262,10	300,21	25,52	25,55	25,44
9	210,00	300,21	25,57	25,57	25,48
10	216,40	300,32	25,50	25,50	25,56
11	191,50	300,25	25,53	25,53	25,50
12	202,30	300,22	25,52	25,51	25,46
13	207,50	300,27	25,46	25,48	25,47
14	200,90	300,30	25,20	25,26	25,25
15	209,20	300,24	25,28	25,34	25,35
16	209,50	300,34	25,47	25,51	25,46
17	259,80	300,02	25,47	25,48	25,50
18	178,10	300,30	25,51	25,53	25,52
19	203,00	300,27	25,58	25,57	25,48
20	228,10	300,20	25,44	25,41	25,40
21	203,80	300,27	25,56	25,45	25,23
22	209,20	300,30	25,51	25,53	25,48
23	213,90	300,28	25,53	25,50	25,48
24	233,70	300,27	25,51	25,49	25,44
25	248,90	300,13	25,53	25,55	25,58
26	188,90	300,25	25,38	25,37	25,35
27	219,00	300,30	25,55	25,56	25,53
28	186,90	300,29	25,53	25,44	25,30
29	223,30	300,23	25,48	25,48	25,45
30	182,60	300,21	25,20	25,26	25,32

Change in length	
Sample	Change
	mm/m
1	0,57
2	0,47
3	0,50
4	0,47
5	0,43
6	0,37
7	0,37
8	0,40
9	0,33
10	0,30
11	0,40
12	0,33
13	0,30
14	0,30
15	0,47
16	0,30
17	0,30
18	0,50
19	0,77
20	0,43
21	0,43
22	0,47
23	0,53
24	0,83
25	0,50
26	0,50
27	0,63
28	0,47
29	0,50
30	0,47
Average	**0,45**

Change in thickness				
Sample	Change			
	1	2	3	Average
	%	%	%	%
1	0,52	0,48	0,40	0,47
2	0,47	0,47	0,43	0,46
3	0,31	0,39	0,51	0,41
4	0,52	0,48	0,56	0,52
5	0,39	0,43	0,43	0,42
6	0,48	0,52	0,48	0,49
7	0,40	0,36	0,36	0,37
8	0,51	0,55	0,55	0,54
9	0,55	0,55	0,51	0,54
10	0,47	0,43	0,59	0,50
11	0,39	0,35	0,47	0,41
12	0,43	0,39	0,43	0,42
13	0,43	0,43	0,43	0,43
14	0,44	0,40	0,48	0,44
15	0,48	0,48	0,56	0,50
16	0,47	0,47	0,47	0,47
17	0,51	0,35	0,47	0,45
18	0,35	0,39	0,47	0,41
19	0,55	0,47	0,47	0,50
20	0,47	0,43	0,47	0,46
21	0,67	0,59	0,44	0,57
22	0,51	0,43	0,31	0,42
23	0,43	0,31	0,35	0,37
24	0,47	0,43	0,43	0,45
25	0,67	0,55	0,59	0,60
26	0,51	0,40	0,32	0,41
27	0,59	0,51	0,43	0,51
28	0,59	0,51	0,44	0,51
29	0,51	0,47	0,51	0,50
30	0,36	0,44	0,44	0,41
			Average	**0,46**

Equilibrium moisture content		
Sample	EMC	
	65% RH	85% RH
	%	%
1	4,15	6,66
2	3,93	6,52
3	3,40	6,20
4	3,97	6,72
5	3,83	6,52
6	4,16	6,79
7	4,11	6,73
8	3,63	5,77
9	3,59	6,06
10	3,89	6,55
11	4,18	6,69
12	4,05	6,53
13	3,73	6,08
14	4,04	6,69
15	4,24	6,90
16	4,02	6,56
17	4,09	6,26
18	3,95	6,52
19	3,83	6,45
20	3,81	6,09
21	3,94	6,98
22	4,39	6,68
23	4,13	6,42
24	3,81	5,89
25	3,81	6,41
26	3,67	6,54
27	4,05	6,99
28	3,70	6,50
29	4,05	6,43
30	4,14	6,41
Average	**3,94**	**6,48**

DESORPTION		Cycle 2	20 C / 65% RH		
Sample	Weight	Length	Thickness		
			1	2	3
	g	mm	mm	mm	mm
1	248,84	300,09	25,39	25,35	25,19
2	216,08	300,20	25,37	25,36	25,41
3	196,36	300,20	25,49	25,51	25,52
4	219,19	300,25	25,50	25,47	25,53
5	201,28	300,20	25,48	25,51	25,47
6	227,44	300,06	25,36	25,35	25,28
7	194,17	300,19	25,41	25,40	25,38
8	265,91	300,10	25,46	25,51	25,52
9	216,62	299,90	25,49	25,48	25,51
10	210,02	300,22	25,50	25,52	25,46
11	191,34	300,18	25,39	25,40	25,44
12	205,08	300,10	25,45	25,49	25,49
13	205,80	300,25	25,41	25,44	25,43
14	197,33	300,25	25,45	25,42	25,42
15	205,61	300,20	25,45	25,46	25,43
16	216,26	300,27	25,50	25,52	25,51
17	255,61	300,13	25,32	25,31	25,21
18	187,23	300,25	25,48	25,46	25,45
19	199,99	300,22	25,47	25,48	25,38
20	226,72	300,12	25,43	25,48	25,49
21	191,71	300,21	25,33	25,31	25,30
22	190,60	300,21	25,31	25,31	25,35
23	213,61	300,18	25,49	25,46	25,43
24	257,19	300,13	25,50	25,45	25,44
25	255,38	300,20	25,54	25,51	25,49
26	208,50	300,24	25,50	25,49	25,49
27	199,21	300,05	25,49	25,50	25,46
28	164,64	300,18	25,44	25,45	25,36
29	231,19	300,14	25,45	25,48	25,47
30	175,07	300,08	25,38	25,47	25,47

DESORPTION		Cycle 3	20 C / 35% RH		
Sample	Weight	Length	Thickness		
			1	2	3
	g	mm	mm	mm	mm
1	245,52	299,98	25,32	25,29	25,11
2	212,95	300,10	25,29	25,27	25,32
3	193,71	300,12	25,39	25,45	25,43
4	216,28	300,16	25,42	25,42	25,44
5	198,78	300,12	25,40	25,43	25,41
6	224,37	299,90	25,29	25,28	25,21
7	191,42	300,08	25,33	25,34	25,31
8	262,78	300,00	25,39	25,45	25,45
9	213,91	299,81	25,42	25,42	25,43
10	207,00	300,12	25,42	25,42	25,38
11	188,88	300,08	25,31	25,34	25,37
12	202,29	300,00	25,37	25,42	25,41
13	203,25	300,16	25,33	25,38	25,36
14	194,71	300,14	25,38	25,36	25,35
15	202,64	300,09	25,36	25,39	25,36
16	213,38	300,15	25,41	25,45	25,43
17	252,61	300,03	25,25	25,26	25,15
18	184,85	300,15	25,40	25,42	25,41
19	197,33	300,11	25,41	25,40	25,32
20	224,15	300,05	25,34	25,41	25,42
21	189,41	300,12	25,26	25,25	25,23
22	187,97	300,10	25,25	25,24	25,28
23	211,31	300,08	25,42	25,42	25,38
24	254,67	300,04	25,43	25,41	25,39
25	252,72	300,12	25,48	25,46	25,41
26	206,50	300,15	25,46	25,46	25,44
27	196,87	299,96	25,43	25,44	25,40
28	162,51	300,07	25,39	25,39	25,31
29	228,57	300,04	25,37	25,41	25,41
30	172,95	299,97	25,32	25,41	25,42

Change in length	
Sample	Change
	mm/m
1	0,37
2	0,33
3	0,27
4	0,30
5	0,27
6	0,53
7	0,37
8	0,33
9	0,30
10	0,33
11	0,33
12	0,33
13	0,30
14	0,37
15	0,37
16	0,40
17	0,33
18	0,33
19	0,37
20	0,23
21	0,30
22	0,37
23	0,33
24	0,30
25	0,27
26	0,30
27	0,30
28	0,37
29	0,33
30	0,37
Average	**0,33**

Change in thickness				
Sample	Change			
	1	2	3	Average
	%	%	%	%
1	0,28	0,24	0,32	0,28
2	0,32	0,35	0,35	0,34
3	0,39	0,24	0,35	0,33
4	0,31	0,20	0,35	0,29
5	0,31	0,31	0,24	0,29
6	0,28	0,28	0,28	0,28
7	0,31	0,24	0,28	0,28
8	0,27	0,24	0,27	0,26
9	0,27	0,24	0,31	0,27
10	0,31	0,39	0,31	0,34
11	0,32	0,24	0,28	0,28
12	0,31	0,27	0,31	0,30
13	0,31	0,24	0,28	0,28
14	0,28	0,24	0,28	0,26
15	0,35	0,27	0,28	0,30
16	0,35	0,27	0,31	0,31
17	0,28	0,20	0,24	0,24
18	0,31	0,16	0,16	0,21
19	0,24	0,31	0,24	0,26
20	0,35	0,27	0,27	0,30
21	0,28	0,24	0,28	0,26
22	0,24	0,28	0,28	0,26
23	0,27	0,16	0,20	0,21
24	0,27	0,16	0,20	0,21
25	0,23	0,20	0,31	0,25
26	0,16	0,12	0,20	0,16
27	0,24	0,24	0,24	0,24
28	0,20	0,24	0,20	0,21
29	0,31	0,27	0,24	0,27
30	0,24	0,24	0,20	0,22
			Average	**0,27**

Equilibrium moisture content		
Sample	EMC	
	65% RH	35% RH
	%	%
1	4,94	3,54
2	5,14	3,62
3	5,06	3,64
4	5,05	3,65
5	5,02	3,72
6	5,10	3,68
7	5,21	3,72
8	4,75	3,51
9	4,80	3,49
10	5,06	3,55
11	5,13	3,77
12	5,11	3,68
13	5,06	3,76
14	5,12	3,73
15	5,35	3,83
16	5,02	3,62
17	5,15	3,92
18	5,00	3,66
19	5,11	3,71
20	4,88	3,69
21	5,11	3,85
22	5,32	3,87
23	4,90	3,77
24	4,55	3,52
25	5,06	3,97
26	4,85	3,85
27	5,26	4,02
28	5,02	3,66
29	5,24	4,05
30	4,98	3,71
Average	**5,04**	**3,73**

APPENDIX 6

Test results of Brinell hardness for ayous

Ayous Reference				
Sample	x	y	xy avg	HBW
1	8,8	8,8	8,8	1,2
2	9,9	9,9	9,9	0,7
3	9,2	9,2	9,2	1,0
4	9,8	9,8	9,8	0,8
5	8,0	7,8	7,9	1,6
6	7,6	7,5	7,6	1,8
7	8,3	8,1	8,2	1,5
8	7,0	7,5	7,3	2,0
9	8,6	8,6	8,6	1,3
10	8,3	8,1	8,2	1,5
11	7,5	7,5	7,5	1,9
12	9,0	8,9	9,0	1,1
13	8,2	8,3	8,3	1,5
14	8,6	8,4	8,5	1,3
15	8,2	8,4	8,3	1,4
16	8,7	8,7	8,7	1,3
17	9,3	9,2	9,3	1,0
18	7,4	7,8	7,6	1,8
19	8,2	8,2	8,2	1,5
20	9,2	9,1	9,2	1,1
21	8,3	8,3	8,3	1,4
22	8,9	8,8	8,9	1,2
23	8,9	8,9	8,9	1,2
24	8,4	8,3	8,4	1,4
25	8,2	8,2	8,2	1,5
26	9,4	9,5	9,5	0,9
27	9,2	9,0	9,1	1,1
28	8,5	8,4	8,5	1,4
29	8,5	8,7	8,6	1,3
30	9,5	9,2	9,4	1,0
Average	8,6	8,6	8,6	1,3

Ayous Thermally modified				
Sample	x	y	xy avg	HBW
1	10,0	10,0	10,0	0,6
2	10,0	10,0	10,0	0,6
3	10,0	10,0	10,0	0,6
4	9,8	9,7	9,8	0,8
5	9,2	9,2	9,2	1,0
6	9,2	9,2	9,2	1,0
7	9,2	9,2	9,2	1,0
8	9,7	9,6	9,7	0,9
9	9,3	9,3	9,3	1,0
10	9,5	9,3	9,4	1,0
11	9,1	9,0	9,1	1,1
12	10,0	10,0	10,0	0,6
13	9,1	8,9	9,0	1,1
14	9,4	9,3	9,4	1,0
15	9,5	9,4	9,5	0,9
16	9,7	9,7	9,7	0,8
17	9,6	9,8	9,7	0,8
18	9,2	9,5	9,4	1,0
19	9,1	8,9	9,0	1,1
20	10,0	10,0	10,0	0,6
21	9,3	9,1	9,2	1,0
22	9,5	9,7	9,6	0,9
23	9,5	9,5	9,5	0,9
24	9,5	9,8	9,7	0,9
25	8,2	8,2	8,2	1,5
26	9,3	9,5	9,4	1,0
27	10,0	10,0	10,0	0,6
28	8,3	8,5	8,4	1,4
29	8,9	8,5	8,7	1,3
30	10,0	10,0	10,0	0,6
Average	9,4	9,4	9,4	0,9

APPENDIX 7

Test results of Brinell hardness for frake

Frake Reference				
Sample	x	y	xy avg	HBW
1	5,1	5,5	5,3	4,2
2	5,6	5,7	5,7	3,6
3	6,6	6,7	6,7	2,5
4	6,6	6,5	6,6	2,6
5	5,5	5,6	5,6	3,8
6	5,6	5,6	5,6	3,7
7	6,3	6,4	6,4	2,8
8	5,5	5,7	5,6	3,7
9	5,5	5,6	5,6	3,8
10	5,8	6,0	5,9	3,3
11	6,3	6,3	6,3	2,8
12	6,6	6,7	6,7	2,5
13	6,0	6,1	6,1	3,1
14	5,9	6,1	6,0	3,2
15	6,3	6,5	6,4	2,7
16	5,6	5,6	5,6	3,7
17	5,0	5,0	5,0	4,8
18	6,2	6,8	6,5	2,7
19	6,2	6,3	6,3	2,9
20	6,0	5,8	5,9	3,3
21	5,8	5,6	5,7	3,6
22	5,4	5,7	5,6	3,8
23	6,5	6,5	6,5	2,7
24	5,3	5,4	5,4	4,1
25	4,5	5,0	4,8	5,3
26	5,5	5,5	5,5	3,9
27	6,0	6,0	6,0	3,2
28	7,0	7,0	7,0	2,2
29	5,1	5,0	5,1	4,7
30	6,2	6,2	6,2	3,0
Average	5,9	5,9	5,9	3,4

Frake Thermally modified				
Sample	x	y	xy avg	HBW
1	5,8	5,9	5,9	3,4
2	6,7	6,8	6,8	2,4
3	7,2	7,0	7,1	2,2
4	6,0	6,1	6,1	3,1
5	6,7	7,0	6,9	2,3
6	6,0	5,7	5,9	3,4
7	7,0	7,2	7,1	2,2
8	5,5	5,7	5,6	3,7
9	6,2	7,0	6,6	2,6
10	6,4	6,3	6,4	2,8
11	7,0	7,0	7,0	2,2
12	7,0	7,0	7,0	2,2
13	7,1	7,1	7,1	2,2
14	7,0	6,8	6,9	2,3
15	7,1	7,0	7,1	2,2
16	6,2	6,0	6,1	3,1
17	7,2	7,2	7,2	2,1
18	6,9	6,5	6,7	2,5
19	6,0	6,8	6,4	2,7
20	7,5	7,5	7,5	1,9
21	7,0	7,0	7,0	2,2
22	6,9	7,0	7,0	2,3
23	6,0	5,8	5,9	3,3
24	5,2	5,5	5,4	4,1
25	6,5	6,2	6,4	2,8
26	6,7	6,5	6,6	2,6
27	7,2	7,1	7,2	2,1
28	6,2	6,2	6,2	3,0
29	7,5	7,5	7,5	1,9
30	6,7	6,9	6,8	2,4
Average	6,6	6,6	6,6	2,6

APPENDIX 8 The results of 4-point bending for ayous

Ayous 4-point bending					
Name	Max_Force	Max_Stress	Max_Ext.1	Max_Stroke	MoE
Unit	N	N/mm2	mm	mm	N/mm2
1 _ 1	1804,7	81,2	1,3	15,1	7329,4
1 _ 2	1573,9	70,8	1,2	12,9	6584,0
2 _ 1	965,6	43,5	1,0	10,0	4733,0
2 _ 2	923,5	41,6	2,2	12,2	4385,3
3 _ 1	1531,1	68,9	1,7	15,5	5777,4
3 _ 2	1604,4	72,2	1,7	16,9	6507,5
4 _ 1	1075,4	48,4	1,7	14,5	4284,6
4 _ 2	1029,3	46,3	1,4	13,1	4292,1
5 _ 1	1474,2	66,3	1,3	14,3	5287,8
5 _ 2	1671,4	75,2	1,5	14,8	6114,1
6 _ 1	1786,3	80,4	1,2	12,0	7291,3
6 _ 2	2084,7	93,8	1,5	14,9	7490,1
7 _ 1	1231,4	55,4	1,8	14,4	4867,9
7 _ 2	1147,9	51,7	1,5	14,7	4090,6
8 _ 1	1436,2	64,6	1,2	10,9	6604,7
8 _ 2	1676,4	75,4	0,8	12,7	7333,9
9 _ 1	1454,7	65,5	1,5	14,0	6094,2
9 _ 2	1364,0	61,4	1,7	15,8	5434,7
10 _ 1	1641,4	73,9	1,8	16,6	6170,8
10 _ 2	1213,0	54,6	1,2	11,0	5154,6
11 _ 1	1371,7	61,7	2,1	13,3	5834,0
11 _ 2	1016,3	45,7	1,3	11,2	4631,4
12 _ 1	1270,3	57,2	1,2	11,7	5326,1
12 _ 2	1222,6	55,0	0,8	14,4	4883,0
13 _ 1	1860,4	83,7	1,9	17,6	6476,5
13 _ 2	1727,3	77,7	1,8	15,9	6354,3
14 _ 1	1611,5	72,5	2,3	19,7	5597,3
14 _ 2	1807,5	81,3	3,1	19,4	6470,4
15 _ 1	2026,7	91,2	1,8	18,4	7539,9
15 _ 2	1685,8	75,9	1,2	14,4	6979,7
16 _ 1	1323,0	59,5	1,7	13,7	5431,6
16 _ 2	1261,9	56,8	1,5	13,8	4877,1
17 _ 1	811,1	36,5	1,0	10,6	3622,6
17 _ 2	1072,9	48,3	2,1	15,9	3889,7
18 _ 1	1849,0	83,2	1,9	17,5	7056,1
18 _ 2	1582,3	71,2	1,6	15,2	5931,9
19 _ 1	1475,4	66,4	1,2	15,3	6345,4
19 _ 2	1554,9	70,0	1,7	15,3	5602,3
20 _ 1	1610,9	72,5	1,8	14,8	6493,7
20 _ 2	1528,5	68,8	1,4	12,7	6702,4

21 _ 1	1865,6	83,9	2,1	18,6	6815,7
21 _ 2	1189,2	53,5	1,0	13,9	5117,7
22 _ 1	1109,0	49,9	1,1	11,4	4794,6
22 _ 2	1151,7	51,8	1,2	11,6	4915,9
23 _ 1	1373,0	61,8	2,1	13,3	5588,5
23 _ 2	1337,7	60,2	15,1	15,2	4974,3
24 _ 1	1438,5	64,7	1,8	15,0	5492,1
24 _ 2	1567,8	70,6	1,4	13,1	6353,4
25 _ 1	1759,5	79,2	2,0	18,6	5335,9
25 _ 2	1320,2	59,4	1,2	14,3	5341,5
26 _ 1	1288,2	58,0	1,6	15,4	5228,7
26 _ 2	1338,5	60,2	1,4	12,7	5741,7
27 _ 1	1373,2	61,8	1,0	14,6	5445,8
27 _ 2	1364,0	61,4	1,7	15,1	5361,8
28 _ 1	1510,9	68,0	1,8	14,5	6145,4
28 _ 2	1472,0	66,2	1,9	14,9	5714,2
29 _ 1	1707,9	76,9	2,2	17,7	6102,3
29 _ 2	1424,0	64,1	1,2	16,2	5324,3
30 _ 1	1445,9	65,1	1,5	14,4	5755,5
30 _ 2	1314,2	59,1	1,0	15,6	5845,1
Average	1445,2	65,0	1,8	14,5	5721,1
Std.Dev.	275,4	12,4	1,8	2,2	924,7
Range	1273,6	57,3	14,2	9,8	3917,3

APPENDIX 9 The results of 4-point bending for thermally modified ayous

Thermally modified ayous 4-point bending					
Name	Max_Force	Max_Stress	Max_Ext.1	Max_Stroke	MoE
Unit	N	N/mm2	mm	mm	N/mm2
1 _ 1	702,4	31,6	0,5	6,1	5116,0
1 _ 2	460,7	20,7	0,4	4,1	4400,3
2 _ 1	853,1	38,4	0,3	8,2	4468,6
2 _ 2	817,5	36,8	0,6	8,7	4480,6
3 _ 1	953,8	42,9	0,7	7,9	5615,5
3 _ 2	1029,0	46,3	1,0	9,4	5665,0
4 _ 1	850,3	38,3	0,9	10,4	3993,3
4 _ 2	787,9	35,5	0,9	8,9	4055,6
5 _ 1	991,5	44,6	0,8	8,3	5444,2
5 _ 2	815,6	36,7	0,4	7,2	4855,3
6 _ 1	1436,8	64,7	0,8	10,0	6573,1
6 _ 2	1056,4	47,5	0,7	7,9	6570,0
7 _ 1	551,1	24,8	0,7	6,5	4325,1
7 _ 2	886,8	39,9	1,1	9,2	4532,4
8 _ 1	352,4	15,9	1,7	2,7	5432,5
8 _ 2	408,0	18,4	0,1	3,1	5109,6
9 _ 1	882,2	39,7	0,7	6,3	6226,6
9 _ 2	898,0	40,4	0,6	7,7	5214,7
10 _ 1	859,4	38,7	0,5	6,1	6210,9
10 _ 2	704,7	31,7	0,6	5,5	5332,8
11 _ 1	691,1	31,1	0,9	7,4	4319,5
11 _ 2	1109,7	49,9	1,1	9,2	5604,0
12 _ 1	999,7	45,0	0,8	8,6	5424,6
12 _ 2	929,6	41,8	0,4	10,0	4901,8
13 _ 1	1276,5	57,4	0,9	9,3	6355,6
13 _ 2	1482,3	66,7	11,2	10,2	6917,3
14 _ 1	730,0	32,9	0,5	6,1	5186,6
14 _ 2	789,8	35,5	0,7	7,1	5361,1
15 _ 1	892,4	40,2	0,5	5,9	6405,1
15 _ 2	993,1	44,7	1,1	6,5	6582,6
16 _ 1	701,0	31,5	0,5	6,4	4871,3
16 _ 2	743,8	33,5	0,7	6,3	5233,0
17 _ 1	561,5	25,3	0,4	5,8	4101,3
17 _ 2	537,2	24,2	0,6	5,9	4101,5
18 _ 1	810,6	36,5	0,5	6,2	5909,1
18 _ 2	942,5	42,4	0,6	6,8	6068,8
19 _ 1	771,1	34,7	1,7	6,7	5122,1
19 _ 2	1094,6	49,3	0,9	9,2	5608,0
20 _ 1	689,3	31,0	0,6	7,5	5203,7

20 _ 2	854,0	38,4	0,8	10,1	5393,0
21 _ 1	955,4	43,0	0,7	7,4	5898,6
21 _ 2	1025,2	46,1	0,8	8,4	5438,2
22 _ 1	1060,5	47,7	0,7	8,9	5433,5
22 _ 2	1019,1	45,9	0,8	7,8	5945,5
23 _ 1	548,3	24,7	0,6	5,5	4262,7
23 _ 2	805,3	36,2	0,9	8,5	4328,8
24 _ 1	747,7	33,6	2,3	7,0	4870,4
24 _ 2	845,2	38,0	0,9	9,0	4350,8
25 _ 1	602,5	27,1	9,8	5,1	4871,5
25 _ 2	958,8	43,1	0,9	8,4	5352,5
26 _ 1	1130,5	50,9	0,7	9,1	5514,1
26 _ 2	1201,2	54,1	0,6	11,5	5291,8
27 _ 1	935,7	42,1	0,6	7,9	5511,2
27 _ 2	841,0	37,8	0,8	7,5	5380,6
28 _ 1	1041,2	46,9	0,8	8,3	5693,4
28 _ 2	912,9	41,1	0,8	8,0	5298,1
29 _ 1	1037,9	46,7	0,8	7,9	5903,9
29 _ 2	1072,5	48,3	1,1	8,3	5829,3
30 _ 1	1001,0	45,0	1,0	9,5	5134,9
30 _ 2	768,2	34,6	0,7	8,2	4062,0
Average	873,4	39,3	1,1	7,6	5277,7
Standard Deviation	220,5	9,9	1,8	1,7	724,6
Range	1129,8	50,8	11,1	8,8	2924,0

APPENDIX 10 The results of 4-point bending for frake

Frake 4-point bending					
Name	Max_Force	Max_Stress	Max_Ext.1	Max_Stroke	MoE
Unit	N	N/mm2	mm	mm	N/mm2
1 _ 1	2090,6	94,1	1,2	10,7	9951,0
1 _ 2	1972,7	88,8	1,6	12,3	9439,1
2 _ 1	2553,3	114,9	1,1	11,8	11407,7
2 _ 2	2758,9	124,1	2,0	16,0	11003,6
3 _ 1	2196,9	98,9	1,3	11,3	9857,5
3 _ 2	2292,5	103,2	1,4	13,5	9408,5
4 _ 1	2652,2	119,3	48,5	13,7	11506,1
4 _ 2	2769,0	124,6	1,4	14,5	11483,3
5 _ 1	2442,7	109,9	1,0	11,7	10561,5
5 _ 2	2580,3	116,1	1,4	14,8	10815,8
6 _ 1	2252,5	101,4	1,3	12,5	9558,5
6 _ 2	2135,4	96,1	1,1	11,6	10100,0
7 _ 1	2632,9	118,5	1,3	15,0	10823,6
7 _ 2	2378,5	107,0	1,1	12,6	10373,4
8 _ 1	1629,0	73,3	0,8	7,3	10609,5
8 _ 2	2242,0	100,9	1,5	11,6	10925,0
9 _ 1	2083,5	93,8	11,9	11,5	9505,7
9 _ 2	2046,8	92,1	5,5	10,8	9868,0
10 _ 1	2827,4	127,2	1,6	15,3	11988,7
10 _ 2	2820,1	126,9	1,6	15,1	11783,1
11 _ 1	2429,7	109,3	1,1	12,0	10756,6
11 _ 2	2265,4	101,9	1,0	11,7	10276,4
12 _ 1	2292,6	103,2	1,1	11,7	10259,0
12 _ 2	2474,7	111,4	1,0	12,7	10305,0
13 _ 1	2297,3	103,4	2,0	13,3	10145,9
13 _ 2	2531,1	113,9	2,1	15,9	9869,6
14 _ 1	2310,4	104,0	1,4	13,6	10406,1
14 _ 2	2304,1	103,7	3,2	12,5	10382,8
15 _ 1	2167,1	97,5	0,9	11,5	9901,3
15 _ 2	2219,8	99,9	1,2	11,6	10360,1
16 _ 1	2395,0	107,8	1,8	12,6	10864,0
16 _ 2	2429,9	109,3	1,7	14,0	10046,2
17 _ 1	2256,6	101,5	1,1	10,9	10922,9
17 _ 2	1645,1	74,0	1,4	10,5	10205,7
18 _ 1	1953,4	87,9	1,3	12,4	9397,1
18 _ 2	2000,1	90,0	1,2	11,7	9003,3
19 _ 1	2053,6	92,4	1,4	11,1	9648,5
19 _ 2	1783,0	80,2	1,3	8,9	9764,3
20 _ 1	2435,2	109,6	2,9	14,0	9766,0

20 _ 2	2739,8	123,3	1,8	13,7	12133,3
21 _ 1	1640,4	73,8	1,2	11,2	7680,4
21 _ 2	1743,7	78,5	1,2	10,0	8690,0
22 _ 1	2309,2	103,9	1,5	13,9	10356,5
22 _ 2	1991,4	89,6	1,3	11,6	9441,6
23 _ 1	1965,4	88,4	4,5	11,3	8982,9
23 _ 2	1813,6	81,6	12,8	10,5	8815,1
24 _ 1	2291,9	103,1	1,6	14,0	9958,5
24 _ 2	1630,0	73,4	0,7	8,0	9707,2
25 _ 1	2764,4	124,4	1,2	14,5	13487,5
25 _ 2	3023,2	136,0	1,2	12,0	13349,7
26 _ 1	2293,2	103,2	1,3	12,4	10037,4
26 _ 2	2519,6	113,4	1,4	13,4	11848,0
27 _ 1	2390,5	107,6	1,2	12,9	10665,2
27 _ 2	2261,5	101,8	1,1	11,2	10736,8
28 _ 1	2286,2	102,9	2,1	14,2	9738,4
28 _ 2	2010,6	90,5	1,2	11,6	9272,3
29 _ 1	2686,4	120,9	1,4	15,1	12491,0
29 _ 2	2500,9	112,5	1,4	12,3	11655,7
30 _ 1	1692,1	76,1	1,0	10,0	8478,2
30 _ 2	1682,3	75,7	1,1	10,5	7951,1
Average	2264,0	101,9	2,7	12,3	10312,1
Std.Dev.	340,8	15,3	6,4	1,8	1134,3
Range	1394,2	62,7	47,8	8,6	5807,1

APPENDIX 11 The results of cleavage for ayous

Name	Max_Force	Max stress	Max_Stress	Max_Stroke
Parameters	Calc. at Entire Areas		Calc. at Entire Areas	Calc. at Entire Areas
Unit	N		N/mm2	mm
1 _ 1	984,557	0,46884	0,46884	1,44633
1 _ 2	612,323	0,29158	0,29158	1,17829
1 _ 3	924,190	0,44009	0,44009	1,47610
1 _ 4	640,837	0,30516	0,30516	1,39579
1 _ 5	1191,51	0,56739	0,56738	1,60996
1 _ 6	1376,77	0,65560	0,65561	1,97979
1 _ 7	676,266	0,32203	0,32203	1,10060
1 _ 8	1371,45	0,65307	0,65307	1,71550
1 _ 9	1035,31	0,49300	0,49300	1,67594
1 _ 10	1103,86	0,52565	0,52565	1,30152
1 _ 11	1374,56	0,65455	0,65455	1,62021
1 _ 12	769,520	0,36644	0,36644	1,27067
1 _ 13	1082,93	0,51568	0,51568	1,18250
1 _ 14	1065,19	0,50723	0,50723	1,31465
1 _ 15	1030,51	0,49072	0,49072	1,30363
1 _ 16	811,895	0,38662	0,38662	1,56313
1 _ 17	850,964	0,40522	0,40522	1,70829
1 _ 18	1210,10	0,57624	0,57624	1,73563
1 _ 19	1030,87	0,49089	0,49089	1,33563
1 _ 20	791,820	0,37706	0,37706	1,78979
1 _ 21	1101,70	0,52462	0,52462	1,56746
1 _ 22	870,816	0,41467	0,41467	1,23565
1 _ 23	739,209	0,35200	0,35200	1,27910
1 _ 24	1115,10	0,53100	0,53100	1,56483
1 _ 25	633,780	0,30180	0,30180	0,98979
1 _ 26	931,883	0,44375	0,44375	1,48498
1 _ 27	1034,82	0,49277	0,49277	1,65398
1 _ 28	1270,58	0,60504	0,60504	1,57031
1 _ 29	904,926	0,43092	0,43092	1,23513
1 _ 30	646,130	0,30768	0,30768	1,18713
Average	972,812	0,46324	0,46324	1,44908
Standard Deviation	227,716	0,10844	0,10844	0,23474
Range	764,447	0,36402	0,36403	0,99000

APPENDIX 12 The results of cleavage for thermally modified ayous

Name	Max_Force	Max stress	Max_Stress	Max_Stroke
Parameters	Calc. at Entire Areas		Calc. at Entire Areas	Calc. at Entire Areas
Unit	N		N/mm2	mm
1 _ 1	486,898	0,24044	0,24044	1,04246
1 _ 2	370,359	0,18289	0,18289	1,08779
1 _ 3	426,134	0,21044	0,21044	0,86748
1 _ 4	526,142	0,25982	0,25982	1,54231
1 _ 5	461,896	0,22810	0,22810	0,67996
1 _ 6	479,841	0,23696	0,23696	0,96629
1 _ 7	467,984	0,23110	0,23110	1,09229
1 _ 8	423,018	0,20890	0,20890	1,43779
1 _ 9	440,009	0,21729	0,21729	0,66746
1 _ 10	531,944	0,26269	0,26269	0,96815
1 _ 11	59,6205	0,02944	0,02944	0,24894
1 _ 12	410,461	0,20270	0,20270	0,96231
1 _ 13	631,746	0,31197	0,31197	1,26794
1 _ 14	496,086	0,24498	0,24498	1,05744
1 _ 15	378,895	0,18711	0,18711	1,37596
1 _ 16	420,364	0,20759	0,20759	1,02263
1 _ 17	311,009	0,15358	0,15358	1,05079
1 _ 18	358,613	0,17709	0,17709	0,99413
1 _ 19	486,867	0,24043	0,24043	1,04413
1 _ 20	425,530	0,21014	0,21014	1,17796
1 _ 21	530,593	0,26202	0,26202	1,06546
1 _ 22	375,875	0,18562	0,18562	0,96998
1 _ 23	448,799	0,22163	0,22163	1,08027
1 _ 24	544,739	0,26901	0,26901	1,18979
1 _ 25	386,556	0,19089	0,19089	0,71313
1 _ 26	452,487	0,22345	0,22345	1,81396
1 _ 27	515,620	0,25463	0,25463	1,20263
1 _ 28	663,980	0,32789	0,32789	1,17163
1 _ 29	701,173	0,34626	0,34626	1,55279
1 _ 30	425,243	0,21000	0,21000	1,13796
Average	454,616	0,22450	0,22450	1,08173
Standard Deviation	115,341	0,05696	0,05696	0,29609
Range	641,553	0,31682	0,31682	1,56502

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APPENDIX 13 The results of cleavage for frake

Name	Max_Force	Max stress	Max_Stress	Max_Stroke
Parameters	Calc. at Entire Areas		Calc. at Entire Areas	Calc. at Entire Areas
Unit	N		N/mm2	mm
1 _ 1	2186,82	0,69423	0,69423	1,26519
1 _ 2	2448,86	0,77742	0,77742	1,34513
1 _ 3	2124,18	0,67434	0,67434	1,40260
1 _ 4	2072,37	0,65790	0,65789	1,33640
1 _ 5	2388,95	0,75840	0,75840	1,50940
1 _ 6	1763,88	0,55996	0,55996	1,07965
1 _ 7	1693,11	0,53750	0,53749	1,34071
1 _ 8	2090,50	0,66365	0,66365	0,92165
1 _ 9	1988,33	0,63122	0,63122	1,21746
1 _ 10	1389,36	0,44107	0,44107	0,99965
1 _ 11	2426,64	0,77036	0,77036	1,57346
1 _ 12	2151,30	0,68295	0,68295	1,35475
1 _ 13	2621,21	0,83213	0,83213	1,48313
1 _ 14	2120,38	0,67314	0,67314	1,40675
1 _ 15	1730,41	0,54934	0,54934	1,25779
1 _ 16	2524,14	0,80131	0,80131	1,31910
1 _ 17	2308,73	0,73293	0,73293	1,11765
1 _ 18	2436,64	0,77354	0,77354	1,64927
1 _ 19	1788,82	0,56788	0,56788	1,09429
1 _ 20	2318,64	0,73608	0,73608	1,19306
1 _ 21	2809,54	0,89192	0,89192	1,30060
1 _ 22	2012,27	0,63882	0,63882	1,41983
1 _ 23	1750,33	0,55566	0,55566	1,20217
1 _ 24	2472,56	0,78494	0,78494	1,32746
1 _ 25	2637,78	0,83739	0,83739	1,14302
1 _ 26	2473,94	0,78538	0,78538	1,45577
1 _ 27	1909,35	0,60614	0,60614	1,37029
1 _ 28	1843,80	0,58533	0,58533	1,37902
1 _ 29	2088,79	0,66311	0,66311	1,26050
1 _ 30	1619,43	0,51410	0,51411	1,11854
Average	2139,70	0,67927	0,67927	1,29481
Standard Deviation	347,237	0,11023	0,11023	0,16626
Range	1420,18	0,45085	0,45085	0,72762

APPENDIX 14 The results of cleavage for thermally modified frake

Name	Max_Force	Max stress	Max_Stress	Max_Stroke
Parameters	Calc. at Entire Areas		Calc. at Entire Areas	Calc. at Entire Areas
Unit	N		N/mm2	mm
1 _ 1	1378,90	0,45963	0,45963	1,12460
1 _ 2	1177,33	0,39244	0,39244	1,15681
1 _ 3	1048,55	0,34952	0,34952	1,35279
1 _ 4	1240,67	0,41356	0,41356	1,68396
1 _ 5	1050,58	0,35019	0,35019	0,98981
1 _ 6	1159,40	0,38647	0,38647	0,88379
1 _ 7	731,293	0,24376	0,24376	0,80429
1 _ 8	1179,03	0,39301	0,39301	0,76579
1 _ 9	1340,56	0,44685	0,44685	1,10681
1 _ 10	1225,52	0,40851	0,40851	1,09402
1 _ 11	984,017	0,32801	0,32801	0,97763
1 _ 12	1088,27	0,36276	0,36276	0,89696
1 _ 13	1197,91	0,39930	0,39930	0,96379
1 _ 14	935,650	0,31188	0,31188	1,01263
1 _ 15	808,271	0,26942	0,26942	0,78013
1 _ 16	1090,57	0,36352	0,36352	0,99929
1 _ 17	1008,07	0,33602	0,33602	1,01613
1 _ 18	808,064	0,26935	0,26935	0,78513
1 _ 19	1087,30	0,36243	0,36243	0,93979
1 _ 20	1119,66	0,37322	0,37322	1,11248
1 _ 21	1037,26	0,34575	0,34575	0,79763
1 _ 22	1183,07	0,39436	0,39435	0,89096
1 _ 23	1417,45	0,47248	0,47248	1,22315
1 _ 24	959,746	0,31992	0,31992	0,81596
1 _ 25	1236,63	0,41221	0,41221	0,87648
1 _ 26	830,444	0,27681	0,27681	0,99279
1 _ 27	1115,21	0,37174	0,37174	0,95663
1 _ 28	926,606	0,30887	0,30887	0,84994
1 _ 29	926,590	0,30886	0,30886	0,78496
1 _ 30	1004,93	0,33498	0,33498	0,90731
Average	1076,59	0,35886	0,35886	0,98475
Standard Deviation	169,499	0,05650	0,05650	0,19539
Range	686,157	0,22872	0,22872	0,91817

APPENDIX 15 The results of screw withdrawal for ayous

Screw withdrawal (Ayous)			
Name	Max_Force	Max_Stroke	Max_Time
Unit	N	mm	s
1 _ 1	1589,2	2,1	63,1
1 _ 2	1730,5	1,4	42,3
1 _ 3	1642,8	1,4	41,4
1 _ 4	1749,4	1,5	45,0
1 _ 5	1672,7	1,4	43,3
1 _ 6	1681,1	1,5	44,0
1 _ 7	1695,5	1,4	42,5
2 _ 1	1136,4	1,2	37,3
2 _ 2	1126,2	1,1	33,9
2 _ 3	1136,8	1,2	36,9
2 _ 4	1187,7	1,2	35,5
2 _ 5	1161,6	1,2	36,7
2 _ 6	1176,5	1,2	35,6
3 _ 1	1566,5	1,9	57,4
3 _ 2	1716,5	1,5	45,3
3 _ 3	1634,1	1,4	41,7
3 _ 4	1592,1	1,4	41,3
3 _ 5	1905,6	1,5	45,7
3 _ 6	1514,4	3,0	89,6
3 _ 7	1691,2	1,3	39,7
4 _ 1	1567,8	1,3	38,2
4 _ 2	1972,8	1,4	41,4
4 _ 3	1740,5	1,3	37,6
4 _ 4	1648,5	1,3	39,6
4 _ 5	1748,0	1,3	39,4
4 _ 6	2048,1	1,4	43,0
4 _ 7	1828,2	1,3	39,8
5 _ 1	1814,0	1,4	42,2
5 _ 2	1992,0	1,5	45,6
5 _ 3	1952,4	1,4	42,8
5 _ 4	1977,4	1,4	42,7
5 _ 5	1881,4	1,5	45,5
5 _ 6	1748,4	1,4	40,6
5 _ 7	1851,2	1,4	43,2
6 _ 1	1917,0	1,5	45,9

6 _ 2	2034,8	1,6	47,1
6 _ 3	1651,8	1,4	41,2
6 _ 4	1779,6	1,5	44,5
6 _ 5	1922,3	1,4	42,1
6 _ 6	2036,9	1,5	45,9
6 _ 7	2105,2	1,5	45,2
7 _ 1	1401,5	1,2	37,0
7 _ 2	1574,2	1,3	38,6
7 _ 3	1567,2	1,3	39,2
7 _ 4	1405,1	1,2	36,5
7 _ 5	1435,3	1,2	37,1
7 _ 6	1212,3	1,2	35,8
7 _ 7	1320,5	1,0	30,9
8 _ 1	2297,0	1,7	52,0
8 _ 2	2435,3	1,8	53,6
8 _ 3	2369,0	1,7	52,1
8 _ 4	2134,8	1,5	45,9
8 _ 5	2199,5	1,6	49,5
8 _ 6	2195,8	1,6	48,8
8 _ 7	2218,4	1,6	48,1
9 _ 1	1382,9	1,5	46,5
9 _ 2	1407,1	1,3	38,0
9 _ 3	1485,1	1,3	37,7
9 _ 4	1460,3	1,4	41,9
9 _ 5	1575,9	1,2	36,1
9 _ 6	1457,2	2,0	60,2
9 _ 7	1598,0	1,3	38,2
10 _ 1	1768,4	1,6	48,2
10 _ 2	2050,9	1,7	51,6
10 _ 3	1989,2	1,5	45,2
10 _ 4	2071,4	1,6	46,6
10 _ 5	1926,5	1,4	42,1
10 _ 6	2101,2	1,5	44,1
10 _ 7	2017,5	1,5	43,5
11 _ 1	1789,8	1,2	36,9
11 _ 2	1867,5	2,1	64,4
11 _ 3	2086,6	1,3	39,8
11 _ 4	2025,4	1,3	38,6
11 _ 5	1883,1	1,2	37,5
11 _ 6	1853,7	1,3	37,8
11 _ 7	2097,7	1,2	37,4
12 _ 1	1386,9	1,3	38,3
12 _ 2	1495,0	1,4	41,2

12 _ 3	1464,2	1,4	40,7
12 _ 4	1348,0	1,3	38,9
12 _ 5	1357,3	1,3	37,9
12 _ 6	1401,2	1,3	39,4
12 _ 7	1306,9	1,2	37,0
13 _ 1	2114,7	1,5	45,6
13 _ 2	2313,6	1,5	45,8
13 _ 3	2196,1	1,6	47,7
13 _ 4	2191,9	1,5	46,5
13 _ 5	2297,2	1,6	47,2
13 _ 6	2315,8	1,6	47,7
13 _ 7	2400,9	1,6	48,9
14 _ 1	2043,9	1,5	45,0
14 _ 2	2197,4	1,6	48,1
14 _ 3	2134,1	1,5	45,0
14 _ 4	2103,4	1,6	46,8
14 _ 5	2104,4	1,6	47,1
14 _ 6	2029,9	1,5	45,7
14 _ 7	2062,9	1,5	45,5
15 _ 1	1774,8	1,5	44,4
15 _ 2	2002,1	1,5	45,1
15 _ 3	2040,9	2,2	64,7
15 _ 4	2007,4	1,5	45,8
15 _ 5	2145,7	1,5	46,4
15 _ 6	2148,5	1,6	48,6
15 _ 7	1885,9	1,4	41,7
Average	1802,5	1,5	44,0
Std.Dev.	329,3	0,3	7,6
Range	1309,1	2,0	58,7

APPENDIX 16 The results of screw withdrawal for thermally modified ayous

Screv withdrawal (Thermally modified ayous)			
Name	Max_Force	Max_Stroke	Max_Time
Unit	N	mm	s
1 _ 1	996,8	0,9	25,9
1 _ 2	1163,7	0,9	25,9
1 _ 3	1156,9	0,8	23,8
1 _ 4	1063,4	0,8	22,9
1 _ 5	947,5	0,8	23,4
1 _ 6	1096,1	0,8	24,4

1 _ 7	1280,2	0,9	26,5
2 _ 1	603,5	0,7	20,8
2 _ 2	703,8	0,8	25,5
2 _ 3	668,7	0,7	20,2
2 _ 4	694,1	0,7	20,0
2 _ 5	657,4	0,8	23,8
2 _ 6	642,8	0,9	27,5
2 _ 7	664,3	0,7	20,6
3 _ 1	943,5	0,8	23,9
3 _ 2	1082,0	0,8	25,0
3 _ 3	1039,1	0,8	23,0
3 _ 4	1027,6	0,8	25,2
3 _ 5	1188,2	0,8	24,0
3 _ 6	1332,1	0,9	27,1
3 _ 7	1030,2	0,7	22,5
4 _ 1	658,9	0,7	21,0
4 _ 2	795,5	0,6	17,1
4 _ 3	782,4	0,6	17,8
4 _ 4	731,6	0,5	16,0
4 _ 5	729,3	0,7	22,1
4 _ 6	760,3	0,6	17,7
4 _ 7	737,0	0,6	19,3
5 _ 1	1205,5	0,8	25,3
5 _ 2	1062,7	0,9	25,8
5 _ 3	1086,1	0,8	24,6
5 _ 4	1069,5	0,9	25,6
5 _ 5	1409,2	0,9	27,2
5 _ 6	1089,2	0,8	22,6
5 _ 7	921,0	0,7	19,7
6 _ 1	972,7	0,8	24,3
6 _ 2	916,6	0,9	27,9
6 _ 3	1013,1	0,7	21,4
6 _ 4	1028,7	0,7	22,2
6 _ 5	1115,1	0,8	23,4
6 _ 6	1127,0	0,8	22,9
6 _ 7	1144,2	0,9	26,6
7 _ 1	838,6	0,7	20,6
7 _ 2	869,5	0,8	23,1
7 _ 3	825,7	0,8	22,7
7 _ 4	805,7	0,8	23,3
7 _ 5	958,6	0,7	20,0
7 _ 6	987,2	0,6	18,7
7 _ 7	939,7	0,6	18,6

8 _ 1	764,0	0,9	26,0
8 _ 2	832,0	0,8	24,9
8 _ 3	813,2	0,8	23,3
8 _ 4	706,3	0,8	23,3
8 _ 5	885,4	0,7	21,9
8 _ 6	909,7	0,7	21,7
8 _ 7	898,3	1,1	33,9
9 _ 1	919,1	0,8	23,6
9 _ 2	971,9	1,0	28,9
9 _ 3	954,4	0,8	25,0
9 _ 4	872,9	0,8	23,3
9 _ 5	923,8	0,8	24,0
9 _ 6	918,6	0,8	24,7
9 _ 7	988,5	0,8	25,3
10 _ 1	906,6	0,9	28,2
10 _ 2	1078,3	0,8	23,7
10 _ 3	931,4	1,2	37,1
10 _ 4	944,1	0,8	24,8
10 _ 5	1029,9	0,8	25,1
10 _ 6	986,6	0,7	22,2
10 _ 7	917,9	0,8	24,0
11 _ 1	835,5	0,7	21,0
11 _ 2	942,4	1,1	31,8
11 _ 3	914,1	0,8	25,5
11 _ 4	903,6	1,0	30,7
11 _ 5	1083,6	1,0	29,9
11 _ 6	1104,5	0,8	23,0
11 _ 7	1120,5	0,7	22,4
12 _ 1	769,5	0,8	24,1
12 _ 2	835,2	0,7	21,2
12 _ 3	815,3	0,8	23,6
12 _ 4	831,5	0,7	21,5
12 _ 5	723,7	0,7	21,7
12 _ 6	787,1	0,7	21,5
12 _ 7	817,5	0,8	23,4
13 _ 1	818,1	0,7	20,0
13 _ 2	952,4	0,6	19,4
13 _ 3	950,2	0,7	22,3
13 _ 4	887,6	0,6	19,0
13 _ 5	904,2	0,8	23,6
13 _ 6	1050,4	0,7	22,5
13 _ 7	1040,1	0,7	20,9
14 _ 1	992,1	0,7	20,6

14 _ 2	1038,8	0,6	19,5
14 _ 3	1034,8	0,9	26,7
14 _ 4	1030,3	0,8	23,2
14 _ 5	905,0	0,9	26,4
14 _ 6	947,1	0,8	25,0
14 _ 7	908,2	0,8	23,1
15 _ 1	471,8	0,8	23,0
15 _ 2	538,3	0,6	18,5
15 _ 3	478,4	0,7	19,6
15 _ 4	419,8	0,4	11,7
15 _ 5	663,8	0,6	19,4
15 _ 6	506,2	0,6	16,7
15 _ 7	452,7	0,5	15,7
Average	906,6	0,8	23,2
Std.Dev.	186,4	0,1	3,7
Range	989,4	0,8	25,4

APPENDIX 17 The results of screw withdrawal for frake

Screw withdrawal (Frake)			
Name	Max_Force	Max_Stroke	Max_Time
Unit	N	mm	s
1 _ 1	3461,4	2,3	70,0
1 _ 2	4001,8	2,7	81,1
1 _ 3	3969,1	2,8	82,9
1 _ 4	3792,4	2,7	82,1
1 _ 5	3906,8	2,7	81,2
1 _ 6	3701,0	2,7	81,5
1 _ 7	3377,1	2,6	78,7
2 _ 1	3561,5	2,6	77,4
2 _ 2	3680,5	2,6	77,7
2 _ 3	3630,6	2,6	79,1
2 _ 4	3583,1	2,6	79,0
2 _ 5	3665,7	2,5	73,8
2 _ 6	3771,6	2,6	77,3
2 _ 7	3652,7	2,7	81,3
3 _ 1	3348,1	2,5	73,9
3 _ 2	3443,8	2,7	82,0
3 _ 3	3425,0	2,5	73,7
3 _ 4	3647,1	3,6	108,9
3 _ 5	3403,9	2,7	80,6

3 _ 6	3429,1	2,6	79,3
3 _ 7	3434,1	4,4	132,5
4 _ 1	3121,6	2,4	73,2
4 _ 2	3159,7	2,3	69,8
4 _ 3	3139,3	2,3	67,7
4 _ 4	2757,2	2,1	63,4
4 _ 5	3113,2	2,4	72,1
4 _ 6	2670,6	2,2	64,6
4 _ 7	2551,6	2,1	61,8
5 _ 1	3156,5	2,4	71,0
5 _ 2	3531,1	2,8	84,7
5 _ 3	3409,9	3,6	109,0
5 _ 4	3536,8	2,8	84,1
5 _ 5	3016,5	2,3	69,5
5 _ 6	3279,9	2,6	76,7
5 _ 7	3207,1	2,4	71,8
6 _ 1	3255,5	2,5	74,3
6 _ 2	3491,3	2,8	85,1
6 _ 3	3539,8	2,7	82,3
6 _ 4	3543,4	2,9	87,5
6 _ 5	3195,8	2,4	73,3
6 _ 6	3353,8	2,8	82,9
6 _ 7	2984,4	2,4	73,2
7 _ 1	2661,4	2,2	65,5
7 _ 2	2220,7	1,8	55,3
7 _ 3	2973,7	2,4	72,6
7 _ 4	2609,8	2,2	65,3
7 _ 5	2589,5	2,1	62,1
7 _ 6	3379,9	2,5	75,7
7 _ 7	2931,4	2,4	73,1
8 _ 1	3163,9	2,6	76,6
8 _ 2	2837,1	2,2	67,4
8 _ 3	3179,5	2,3	69,4
8 _ 4	2900,8	2,4	72,5
8 _ 5	3237,8	2,5	74,5
8 _ 6	3419,6	2,7	80,6
8 _ 7	3216,4	2,5	75,8
10 _ 1	2913,1	2,5	75,7
10 _ 2	3489,8	2,9	87,9
10 _ 3	3563,0	2,9	87,8
10 _ 4	3062,5	2,6	77,4
10 _ 5	3213,4	2,6	76,6
10 _ 6	3129,8	2,4	72,1

10 _ 7	3269,1	2,7	81,0
11 _ 1	2941,8	2,5	74,7
11 _ 2	2997,1	2,5	73,7
11 _ 3	3227,8	2,9	86,5
11 _ 4	3058,8	2,6	77,6
11 _ 5	2713,6	2,2	65,8
11 _ 6	2819,9	2,3	70,2
11 _ 7	2848,4	2,5	75,7
13 _ 1	3360,3	2,6	78,8
13 _ 2	3438,6	2,8	85,3
13 _ 3	3244,9	2,9	86,6
13 _ 4	3314,7	2,6	77,2
13 _ 5	3500,5	2,9	88,2
13 _ 6	3408,9	2,9	85,8
13 _ 7	3136,0	2,6	77,3
14 _ 1	2650,2	2,4	71,8
14 _ 2	2858,0	3,6	107,1
14 _ 3	3075,8	2,4	72,5
14 _ 4	2565,6	2,3	69,3
14 _ 5	3243,4	2,5	75,1
14 _ 6	3280,8	2,7	81,5
14 _ 7	3171,4	2,5	75,9
15 _ 1	2891,1	2,5	75,3
15 _ 2	3054,9	2,7	80,9
15 _ 3	3097,6	3,6	107,7
15 _ 4	2825,5	2,3	67,8
15 _ 5	2894,9	2,4	71,6
15 _ 6	2573,4	2,2	66,8
15 _ 7	2525,2	2,3	69,3
16 _ 1	3557,7	2,7	82,5
16 _ 2	3311,7	3,0	90,8
16 _ 3	3323,3	2,7	81,3
16 _ 4	3064,6	2,8	83,7
16 _ 5	2931,7	2,6	78,5
16 _ 6	3098,8	2,5	75,3
16 _ 7	2958,0	2,6	77,8
17 _ 1	2959,6	3,0	90,7
17 _ 2	2839,3	2,8	83,1
17 _ 3	2720,0	2,5	75,3
17 _ 4	2606,0	3,0	90,9
17 _ 5	4735,6	3,8	115,1
17 _ 6	4948,0	4,4	131,1
17 _ 7	4917,1	4,3	129,8

18 _ 1	2870,3	2,7	80,5
18 _ 2	3363,5	2,8	83,1
18 _ 3	3103,0	2,5	75,8
18 _ 4	3090,3	2,5	75,0
18 _ 5	3140,5	2,7	80,8
18 _ 6	3107,1	3,1	93,5
18 _ 7	3069,9	2,4	71,2
Average	3225,9	2,7	79,6
Std.Dev.	436,9	0,4	12,9
Range	2727,3	2,6	77,2

APPENDIX 17 The results of screw withdrawal for thermally modified frake

Screw withdrawal (Thermally modified frake)			
Name	Max_Force	Max_Stroke	Max_Time
Unit	N	mm	s
1 _ 1	2594,9	1,7	50,8
1 _ 2	2518,5	1,6	47,2
1 _ 3	2449,5	1,5	46,4
1 _ 4	2560,6	1,5	44,2
1 _ 5	2807,6	1,5	43,6
1 _ 6	2519,8	1,4	42,6
1 _ 7	2886,2	2,5	75,7
2 _ 1	2559,4	3,6	109,5
2 _ 2	2910,5	1,6	47,7
2 _ 3	2952,5	1,6	47,9
2 _ 4	1934,5	1,2	37,2
2 _ 5	2136,9	1,2	37,1
2 _ 6	2165,0	1,4	40,8
2 _ 7	2119,2	1,3	39,3
4 _ 1	2343,2	1,4	42,6
4 _ 2	2501,0	1,4	43,1
4 _ 3	2593,0	1,5	45,3
4 _ 4	2522,7	1,5	43,9
4 _ 5	2137,0	1,2	36,3
4 _ 6	2374,1	1,4	41,0
4 _ 7	2283,8	1,3	39,8
5 _ 1	1951,4	1,2	36,1
5 _ 2	1960,2	1,3	38,6
5 _ 3	1910,6	1,3	39,6
5 _ 4	1783,3	1,2	34,6

5 _ 5	2045,1	1,1	33,4
5 _ 6	1953,4	1,1	33,9
5 _ 7	1853,7	1,1	34,2
6 _ 1	2264,9	1,2	37,1
6 _ 2	2286,2	1,3	39,6
6 _ 3	2415,0	1,2	36,9
6 _ 4	2236,7	1,2	37,3
6 _ 5	2698,0	1,4	41,2
6 _ 6	2463,5	1,2	37,3
6 _ 7	2556,9	1,5	43,7
7 _ 1	1538,6	1,0	31,2
7 _ 2	1880,8	1,1	34,0
7 _ 3	2029,4	1,2	35,6
7 _ 4	1748,0	1,2	36,1
7 _ 5	2110,4	1,3	38,5
7 _ 6	1777,6	1,3	38,0
7 _ 7	1776,5	1,2	37,4
8 _ 1	3227,9	1,6	47,4
8 _ 2	3190,2	1,7	49,9
8 _ 3	3475,9	1,7	51,4
8 _ 4	3514,0	1,8	52,7
8 _ 5	3181,1	1,6	48,1
8 _ 6	3250,2	1,7	50,9
8 _ 7	2231,8	1,4	41,3
9 _ 1	2420,1	1,5	44,4
9 _ 2	2413,9	1,3	39,7
9 _ 3	2242,4	1,3	39,7
9 _ 4	2329,4	1,2	34,6
9 _ 5	2522,8	1,3	39,4
9 _ 6	2476,9	1,3	40,2
9 _ 7	1544,3	1,0	29,9
10 _ 1	2328,6	1,3	39,4
10 _ 2	2500,1	1,4	41,9
10 _ 3	2537,8	1,4	43,1
10 _ 4	2406,3	1,2	35,8
10 _ 5	2291,6	1,3	40,1
10 _ 6	2456,5	1,3	38,2
10 _ 7	2205,8	1,2	37,5
11 _ 1	1964,9	1,2	35,7
11 _ 2	2068,7	1,1	33,6
11 _ 3	2070,9	1,3	37,8
11 _ 4	1889,8	1,3	39,5
11 _ 5	2113,3	1,2	35,6

11 _ 6	1899,0	1,3	40,2
11 _ 7	2101,9	1,2	36,4
12 _ 1	2288,1	1,2	37,0
12 _ 2	2390,6	1,3	38,9
12 _ 3	2432,2	1,3	37,8
12 _ 4	2290,3	1,2	37,3
12 _ 5	2304,0	1,3	38,6
12 _ 6	2173,0	1,3	40,5
12 _ 7	2324,7	1,3	39,6
13 _ 1	2261,3	1,3	37,6
13 _ 2	2380,0	1,3	38,6
13 _ 3	2360,8	1,3	38,4
13 _ 4	2422,5	1,2	37,2
13 _ 5	2374,8	1,3	38,0
13 _ 6	2402,5	1,2	37,0
13 _ 7	2486,1	1,2	36,4
14 _ 1	1925,3	1,2	36,7
14 _ 2	2121,2	1,3	39,0
14 _ 3	1929,6	1,1	32,5
14 _ 4	2047,4	1,2	34,8
14 _ 5	1998,1	1,1	34,3
14 _ 6	2129,4	1,2	37,3
14 _ 7	2161,7	1,1	34,1
15 _ 1	2146,2	1,1	33,3
15 _ 2	2285,9	1,2	35,5
15 _ 3	2171,1	1,2	34,7
15 _ 4	2174,9	1,2	36,0
15 _ 5	1833,3	1,2	35,1
15 _ 6	1765,1	1,2	35,3
15 _ 7	2120,6	1,2	35,1
16 _ 1	2327,8	1,4	41,4
16 _ 2	2172,1	1,3	39,3
16 _ 3	2334,2	1,4	41,7
16 _ 4	2382,8	1,3	39,3
16 _ 5	2719,2	1,3	39,5
16 _ 6	2541,4	1,5	44,3
16 _ 7	2481,1	1,2	36,5
Average	2308,4	1,3	40,2
Std.Dev.	368,1	0,3	8,8
Range	1975,4	2,7	79,5